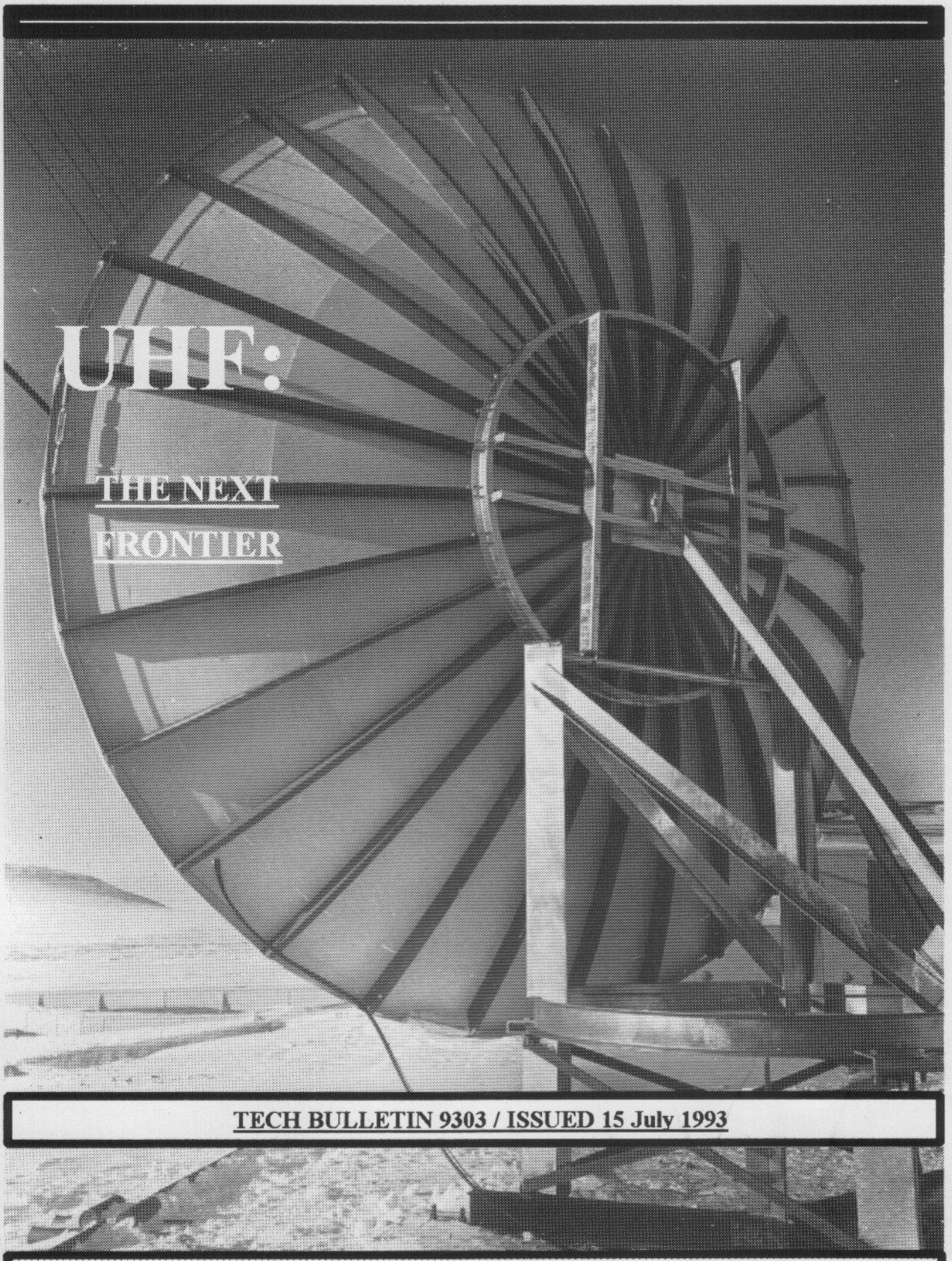

UHF:

THE NEXT FRONTIER

TECH BULLETIN 9303 / ISSUED 15 July 1993

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A FEW WORDS FROM THE PUBLISHER

QUOTES FROM READERS/RFS CHANGES NAME/EUROPEAN DIGITAL TESTS/DO IT YOURSELF TAUPO-STYLE/COMBINING OPPOSITE POLARISATIONS/HELPFUL MINISTRY

Response from the trade to TECH BULLETINS 9301 (Co-Channel Interference Elimination) and 9302 (Weak Signal Reception Techniques) has been excellent. This quotation (which we admit made our day when received) is typical:

"...they contain a lot of detail and should be of great interest to the Trade. If I were starting out on my career I would be waiting at the mailbox for the next issue..."

Radio Frequency Service (RFS) is now officially Radio Operations Group (ROG); the field arm of the Ministry of Commerce. The name-change reflects the broader scope of field operations day to day chores.

Digital television broadcasting is now being tested in U.K., USA and Germany. London/Crystal Palace transmitter (50w ERP; channel 28) compresses 216 Mbps original D-1 format video down to 10 Mbps for transmission of 1,250 line / 16:9 aspect ratio HDTV or conventional 625 line PAL 4:3 aspect ratio video at 3.5 Mbps digitized rate. Similar tests with NTSC 525/30 using over-air band V transmitters on paths to 160 km affirm 'robust nature' of digital video transmissions. Both U.K. and American tests report error-free video (plus audio) reproduction on signals exhibiting carrier to noise ratios as low as 20 dB. Ghosting (multi-path) effects are totally eliminated and within the 8 MHz wide band IV or V spectrum now used for a single analogue TV programme transmission three (3) totally separate programmes can be / are being transmitted in digital format.

Earlier this year virtually every standards group in world (ISO, CCITT et al) reached agreement on single worldwide digital video base-standard (called MPEG-2). This agreement freed up next-generation TV receiver (transmitter) designers to complete and release working proto-type units for field testing. First generation digital processing TV receivers are expected in dealer hands before mid 1994; U.S. FCC has advised TV stations and networks they have until June 29, 2008 to convert to digital telecasting. Because digital 'channels' are only 1/3rd width of analogue channels and the digital format generates virtually no out-of-channel (sideband) products, entirely new channel allocation schemes coming (such as all channels 'adjacent' to one another in a single market like Auckland). U.K. authorities expect to reduce transmitter powers to no less than 1/100th of existing powers for same coverage they now have. A special issue of TECH BULLETIN to deal with these massive changes; shortly.

North Island community of Taupo, faced with shortage of TV3, did it themselves at community level. Taupo also started its own TV2 relay in 1977; raised $15,000 to fund own Concert Network 100 watt translator in 1986. We'll tell you how a community can help itself in future TECH BULLETIN.

If your area has vertical and horizontal channels from same direction and you are looking for creative way to merge signals without creating interference, stay tuned for TB9304; 15 September!

TECH BULLETIN salutes **Ian Hutchings** of Ministry of Commerce for his willingness to help us sort out proper techniques for obtaining licensing for UHF 'OCB' (on channel boosters) described in this issue. Hutchings' work at skillfully interpreting often confusing rules and licensing procedures will appear in an early edition of Tech Bulletin.

TECH BULLETIN 9303

UHF- THE NEW FRONTIER

The Ultra High Frequency assignment for television occupies the region from 518 MHz to 805.10 MHz; TV channels 27 through 62. We refer to these frequencies as bands IV and V, in the European format. Although channels 27 to 62 are contiguous without break, channels up to 600 MHz fall into band IV while channels above 600 are in band V. In New Zealand, channels 27 to 34, and, channels 43 to 62 have been 'sold' by government auction to private firms with 20 year management rights. Channels between 34 and 43 are allocated as follows:

1) Channels 35-36-37 and 38 (582-614 MHz) are reserved for use by Maori broadcasting;

2) Channel 39 is used, on a secondary-use basis, for amateur (ham) radio use and in centres such as Wellington this channel is occupied by one or more Ham-TV stations.

3) Channels 39-40-41 and 42 are reserved for something known as 'non-commercial television' (*).

As a practical matter, and as a direct result of government auction of 20 year frequency (channel) management rights, how and when new TV stations begin to operate in the UHF range will be decided by business people exercising business judgment about the economic feasibility of such stations. It is worth noting that in a handful of locations (such as Waitangirua; channels 46 and 50) BCL operates typically 10 watt or less power TV translators in the UHF band. Additional (new) UHF relays for TV3 are scheduled for Baxter's Knob (100w/ch.42/07-93) and Forest Heights (100w/ch.39V/08-93).

Canterbury Television (Christchurch) operates on UHF. SKY Television uses UHF exclusively for its service, and the new TAB transmitters are UHF. Promises of new 'regional' transmitters, not affiliated with any existing broadcaster, for major centres such as Auckland et al all involve further use of UHF.

VHF channels 1-11, comprising band I (channels 1-3) and III (channels 4-11), are for practical purposes all-used-up in New Zealand. Early-entrants (TV1 and TV2, and the later start-up of TV3) have taken (or reserved for future use) virtually every possible VHF channel in New Zealand. TV expansion; that is, new stations, will be forced by a shortage of VHF frequencies to utilize UHF channels to operate.

IS UHF DIFFERENT THAN VHF?

Yes. VHF channels in New Zealand have a bandwidth of 7 MHz (i.e., channel 1 = 44-51 MHz) while UHF channels have a bandwidth of 8 MHz (i.e., channel 27 = 518¬526 MHz). NICAM stereo, a recent addition to television broadcasting, requires a 510 kHz (.510 MHz) bandwidth under full modulation and falls 5.850 MHz above the video carrier frequency. On channel 1, the visual carrier frequency is 45.250 (nominal without offset) and the NICAM stereo sub-carrier falls on 51.10 MHz. Thus at VHF spectrum the NICAM sub-carrier is actually within the next upper adjacent channel on many channels. On UHF the NICAM stereo signal remains +5.850 MHz reference the video carrier frequency, but with 8 MHz channel-width it falls inside the channel assignment. This is a technical difference peculiar to NICAM stereo. There are many (more important) VHF vs. UHF differences as well.

1) Manmade noise sources, such as electric fences, fishtank heaters, light dimmer controls and combustion engines generate 10-30 dB more noise at band I than at bands IV or V.

2) The wavelength at channel 27 is 8.7% of a wavelength at channel 1. Antennas, designed to capture channel 27 signals, are therefore .087 the size of channel 1 signals for comparable antenna gain (numbers).

3) Transmission line losses (for the transmitter and the receiver) are far greater at band IV (or V) than at band I; an example. In 100 metres of RG-6/U (7 foam series) cable, you will lose 4.0 dB at channel 1 and 11.6 dB of signal at channel 27.

4) The TV receiver found in the typical home has a noise figure (i.e., resistance to producing quality pictures) from 5 to 8 dB worse at bands IV and V than at band I (or III). Therefore, the UHF portion of the TV receiver is 5 to 8 dB less sensitive at UHF than at VHF.

5) Propagation; or, the way signals convey between the transmitter and the receiver site. Because the physical wavelength in space is so much smaller (see #2 above) at bands IV and V, than at band I (or III), we find far greater variations in small increments of 'space' at UHF than at VHF. Example?

Move a band I antenna one metre left or right, up or down. The change in received signal level will seldom exceed 1 dB. Now in the same 1 metre box move a UHF antenna, and watch the signal level variation on a field strength meter. A 10 dB change is not unusual.

All of this says that the tricks of the trade we learned on bands I and III must be relearned at bands IV/V. It is much like returning to school all over again!

IS UHF INFERIOR TO VHF?

Surprisingly perhaps, no. In fact, as the U.K., Holland and other countries have learned from experience, UHF is in many ways a superior portion of the spectrum for the demanding requirements of television transmission. Any early thoughts you may hold to the contrary will hopefully be 'corrected' by the end of this Tech Bulletin.

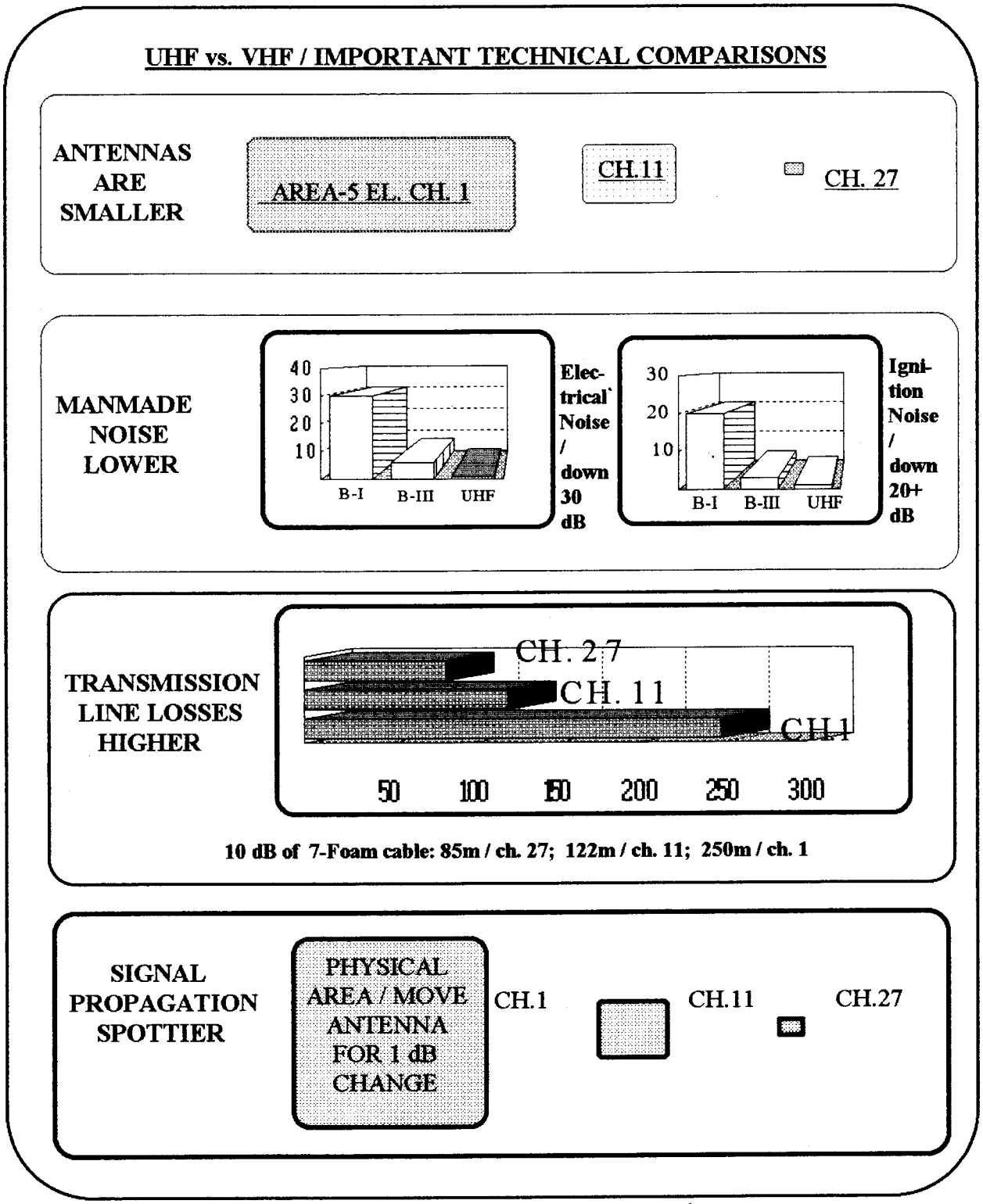
One of the most important pluses to UHF (versus VHF) is receive-system antenna gain. While it is within the realm of possibility to create a receive antenna system with 25 dB of gain at VHF (it takes 64 yagis, ten elements each), few will ever find a client with the dollars or desire to fund such a mammoth undertaking. At UHF, however, for around $500 in materials you can create just such a 25 dB gain antenna; as we shall see in this Tech Bulletin. Another almost-as-important plus to UHF (versus VHF) is your ability as a receive system designer to create a truly low noise front end for the customer; a noise figure as low as 0.5 dB that works to extract signals which would remain buried in manmade noise at either band I or III. Yet another plus to bands IV and V is the simplistic design criteria for creating a system called an on-channel-booster; a technique for relaying a UHF signal (or signals) from a hilltop up to 2 kilometres down into a valley or other shielded/shadowed area where direct

* / WHAT ABOUT LOW POWER AND NON-COMMERCIAL UHF (CHS. 35-42)?

Non-commercial channels (35-42) are reserved for nonprofit broadcasters including Maori groups. Qualified applicants would include regional/local, access, student/educational and religious groups. Initial license term is 3 months with renewals upon proof the station is following the guidelines established. Licenses are granted when:

1) It is clear the applicant is ready to begin telecasting within the first 90 day period;
2) The license will not be utilized for any 'for-profit' purpose(s);
3) Any subsidiary activity, such as the selling of receiving equipment, is not for profit;
4) Any profits that do accrue shall be expended towards improving the broadcasting station or donated to a non-related nonprofit organization;
5) Licensees should be prepared to 'share' channel time with other similar organizations (i.e., there is room in the spectrum for only a limited number of such stations);

Within the reserved spectrum there is also an interim provision for Low Powered In-House Broadcasting. Schools, hospitals, even business premises may operate a TV station with coverage limited essentially to their own immediate premises. The interim procedure requires applicants to operate on the UHF channel immediately adjacent to the locally reserved non-commercial channel; i.e., in Auckland the appropriate such channel is 42, with a radiated power of not more than 0.5 watts EIRP (approximately 0.35 watts to a dipole antenna) and in no case radiate a signal that exceeds 70 dBuV/m (i.e., 3,160 microvolts as measured on an approved test antenna) at the outer boundary of the facility (such as the perimeter of a hospital grounds). Initial license term one year; renewable. Interim policy is a guideline; applicants are handled on a case by case basis.



shielded/shadowed area where direct reception is impossible. We'll explore those techniques here as well.

There is at least one more important plus to UHF (versus VHF), although it may be a temporary advantage in New Zealand. The lack of co-channel interference at UHF, versus the almost assured presence of on-channel TV station interference at VHF (see Tech Bulletin 9301; issued 01-06-93). Dragging VHF channels to distant reception points is often not limited by a lack of signal, but rather by a lack of clean signals free of co-channel interference. With the limited number of UHF TV transmitters on the air,

this should not be a major problem in New Zealand for many years.

UHF - BEYOND THE HORIZON

The first regular use of frequencies above 300 MHz began in the 1938-39 era. Broad tuning, high noise figure receivers coupled with self-excited modulated oscillator transmitters seemed to confirm that as technology pushed higher and higher into the radio spectrum, coverage ranges became more and more line-of-sight limited.

However, as receiver and transmitter and antenna techniques improved, quite the opposite was found to be true. It was in 1935 that experimenters discovered path lengths to more than 200 kilometres were consistently available for communication in the 'very-high' frequency region; regardless of weather, sunspots, skip or any other then-understood phenomenon. Research into this not-understood 'mystery' had priority during World War Two because at that time using VHF-UHF frequencies for tactical troop communications was considered to be a form of security. If, as it would turn out, VHF and UHF signals could be received well beyond the horizon, then carefully constructed listening posts might eavesdrop on these otherwise secret communication paths.

In the realm of television broadcasting, the BBC had closed down its experimental Crystal Palace transmitters in September of 1939; concerned that by leaving them on the air, enemy (i.e., German) planes (and later the V2 rockets) might use these signals to range in on London. When German troops occupied Paris, they chose to maintain operation of an experimental French TV transmitter; using it to broadcast daily film footage of Allied bomb attacks from all over the front. The Germans believed the broadcasts were secure; not capable of being received beyond the Parisian suburbs. Only at war's end was it revealed that 188 km from Paris, at a cliff-site bordering the 'Channel', the Allies created a massive aerial allowing them to tune-in the near nightly German TV film-footage. This made possible direct Allied analysis of their bombing raids, courtesy of German provided film footage transmitted via television! The Germans never suspected they were assisting the Allied intelligence gathering work in this way.

None of this seems unusual today in a world encircled by intelligence gathering satellites. But in 1942-44 this was edge-of-technology cloak and dagger stuff. Allied commanders considered it so hush-hush the entire project had the highest possible level of security cover.

Here is what we know today:

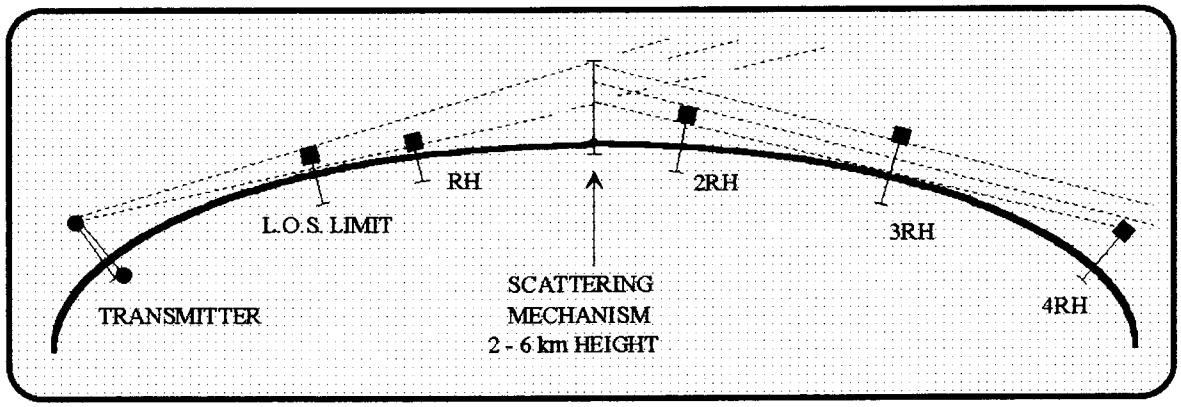
1) VHF and VHF signals do not simply 'cease' at the 'horizon'. When the signal loses line-of-sight (i.e., the receiving antenna can no longer 'see' the transmitting antenna), there is a marked reduction in signal level at the receiver. But, after this initial signal drop, the additional signal attenuation per kilometre/mile of path is actually quite manageable.

2) When you lose 'direct path' signal, the propagation medium (i.e., method by which the signal finds its way to you) becomes one or more forms of something called 'scattering'. A signal arriving via scatter may follow two or more simultaneously distinct 'pathways' from the transmitter to you. This has the effect of causing the signal level to fade, rapidly and randomly, over a range of from 3 to 30 dB. How's that?

If the scatter path to you is actually several different pathways, some will be longer (and some will be shorter) in physical distance than others. The signal requires longer (i.e., more time) to follow the longer pathways than the shorter pathways. This extra time causes the longer pathway signals to be delayed, in time, from the shorter pathway signals. This difference in time is very minuscule, but sufficient to cause the longer and shorter pathways to 'collide' at your antenna out-of-phase; i.e., no longer in sync or in-phase with each other.

When there are two paths, and one is just enough longer that its signal arrives at your antenna 1/2 wavelength (in time) behind the shorter path signal, the two signals are

THE ZONES OF (VHF) UHF COVERAGE



LINE OF SIGHT / Transmitter and Receiver can 'see' one another. **RADIO HORIZON** / Additional area reached by 'direct wave' out to line of sight + 1/3rd line of sight distance. **2RH** / Twice the radio horizon, area that can be served by 14-18dB gain antennas, masthead boosters although signals subject to much day to day variation and co-channel interference prone. **3RH** / Requires 22-25 dB gain antennas, careful phasing to control co-channel interference. **4RH** / Requires 25-30 dB gain antennas, pinpoint directivity to control co-channel interference. Typical distances: LOS - 50km; RH - 65km; 2RH - 130km; 3RH - 190km; 4RH - 250km.

completely out of phase with one another (i.e., 180 degrees out of phase; see Tech Bulletin 9301 relating to phase canceling of co-channel signals). This is like mathematics, adding two columns of numbers together; you have plus 90 in one column and minus 90 in the second column. **The net result is 0.**

In this example, two signals arriving 180 degrees out of phase are respectively +90 and -90 in phase degrees. When the two-path-signals collide at the receiving antenna, they cancel one another. And the net effect is zero; i.e., no signal at all (a very deep fade!).

Setting this example aside, in the real world a beyond-the-horizon receiving site has not one nor two separate path signals; there may be several dozen all at the same time. Some are a tad longer, some a minuscule shorter in path length and from these numerous pathways a few of the signals add together, and a few subtract from the overall signal level present.

Bottom line? Rapid, very erratic fading, Very quick fading; so fast you can't really see it nor measure how often it happens or for long it happens lacking super sophisticated test-measurement equipment.

Does that make 'scatter pathways' useless for television transmission? Not at all. Only challenging.

IT'S ALL ABOUT dBs

A table (page 7) summarizes some of the more relevant points concerning beyond the horizon systems. It's a fair question to ask why, if this sort of signal propagation has been observed since the 1930s, is it not more widely known nor practiced.

1) Television (and VHF FM broadcast) services have been engineered to fit the most common denominator. That is, the engineering that establishes TV (FM) transmitter power levels assumes a 'norm' for something known as a 'standardized TV receiver'.

a) Such a receiver has an anticipated bandwidth and threshold of sensitivity; and, it is connected to the airwaves with a receiving antenna of anticipated gain and directivity.

b) Transmitters, to serve these 'standardized receivers', are located at elevated (hill or mountain top) sites to create line-of-sight paths to as many homes as possible and, when lacking line-of-sight, the next best thing to it; '**radio line-of-sight**' (RLOS).

Radio line-of-sight means the receiving location is not more than 33% beyond the (visual) line-of-sight horizon. If the transmitting antenna tower can 'see' thirty kilometres in a particular direction, radio line-of-sight is 30 + .33 or 10 more kilometres; 40 kilometres total.

Anything beyond radio line-of-sight does not exist as far as system engineering is concerned, when computing coverage areas.

It turns out this localized approach to computing television/FM broadcasting regions works quite well until ... . Until you do something with the equation to upset the radio line-of-sight limitations built into the planning. Transmitter power is one such variable. As transmitter power is increased, say to 100,000 watts, new thresholds appear; thresholds which were invisible at transmitter powers of 10 watts or even 1,000 watts.

If the standardized TV receiving system is built around the assumption that all TV antennas will have 5 dB of forward gain, and someone installs a receiving antenna with 25 dB of gain, another threshold is violated.

Basically, a standardized receiving system married to a standardized transmitting system creates the normal service ranges.

And scatter?

Standardized systems do not allow for nor consider scatter as a relevant propagation mechanism.

It's all a matter of decibels.

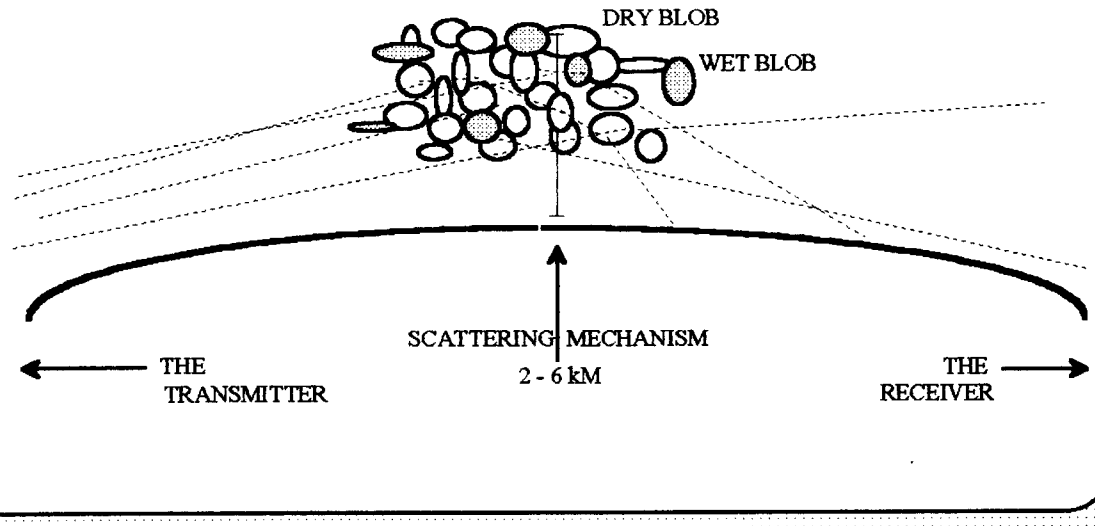
THE THRESHOLD FOR SCATTER

The transition from line-of-sight to scatter is not abrupt; in fact, that's where **radio** line-of-sight comes in. Some definitions:

a) Line Of Sight - Perhaps with the aid of visual magnification (i.e., binoculars), the receiving antenna can literally 'see' the TV transmitting antenna.

b) Blocked / Line-of-Sight - Some object or objects in the way (hills, buildings, trees) but if they were removed, the receiving antenna would be able to 'see' the transmitting antenna.

c) Horizon - If the earth were smooth (such as over a calm sea), the furthest point



THE SCATTERING MECHANISM / MULTIPLE PATHS-HEAVY FADING

LAYERS OF SIGNAL enter the scatter-region from the transmitter. The scatter-mechanism is not a point nor layer; it consists of hundreds/thousands of small (wavelength-plus on any frequency) 'blobs' or air-cells which are in motion. Dry-cells, wet cells and those in between are all homogenized and moving. Where cell boundary lines occur, refraction (scattering) takes place. And the 'mix' is changing, all of the time.

which can be 'seen' from the transmitting antenna. This is the same as the outer edge of the line of sight region.

d) Radio Line-of-Sight - The 'value-added' region that begins at the visual horizon and extends outward away from the transmitter by a distance equal to 1/3rd the total distance from transmitting antenna to the horizon; i.e., the last ten kilometres in a 40 kilometres radio line-of-sight path with its visual horizon at 30 kilometres.

e) Radio Horizon - If the horizon is the limit of visual line of sight, it follows that radio horizon is the outer edge of the value-added region.

Between 'horizon' and 'radio horizon' (VHF and) UHF signals decline rather rapidly; a function of operating frequency. But, and this is where the theory of the 30s missed, it is not so rapid a signal level decline that nothing is left as the signal exits the radio horizon point. A table here (page 7) shows the surprising truth of how much signal remains; not just at 'radio horizon + 1 kilometre' but at 2RH, 3RH and even 4RH.

So in truth scatter is admittedly weaker than normal reception. That's a minor design problem, at least out to distances approximating 3RH. And there is no real 'threshold for scatter' after all.

THE FREQUENCY ELEMENT

Scatter (more correctly, atmospheric scatter since there are several forms of scatter some of which occur over distances to 2,000 [+] km via the elevated layers of the ionosphere) occurs in layers of air 2-6 km above the earth. Studied extensively in the 50s-60s and 70s, the mysteries of 'why scatter' are now mostly explained.

Air temperature declines with increasing altitude. Moisture content of the air also declines but not as linearly as temperature. Moisture content (i.e., humidity) is in pockets, with (relatively) dry cells surrounded above, below, left and right by (relatively) wetter cells. The border or boundary lines between cells creates a signal refraction zone; a point or area at which VHF and UHF signals bend back to earth. These cells are seldom stationary, being constantly 'excited' by moving air bubbles in the lower atmosphere.

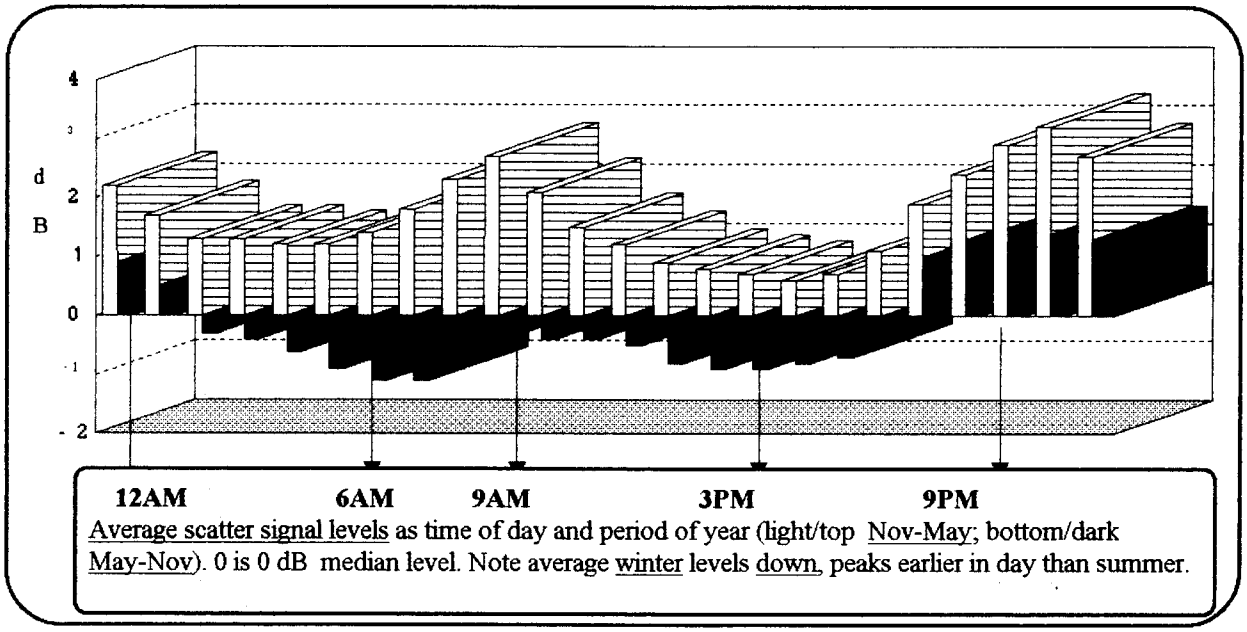
As the earth and clouds warm in the daytime, heat 'bubbles' upward bouncing the wetter and dryer cells about. Only as the earth cools at night does cell movement calm down.

Each cell-to-cell **boundary** is a signal refraction point; an area where the distant TV transmitter signal is intercepted, caught, and bounced back down towards earth. And at any given instant there are hundreds, indeed thousands of such cells bouncing about along the path between the distant TV transmitter and your receiving location. Since each moving cell-to-cell boundary is a refraction point, it should be clear how dozens or even

IDEALIZED SIGNAL LOSSES FROM LINE OF SIGHT OUTWARD

FREQUENCY BAND	REFERENCE LEVEL AT LINE OF SIGHT	AT RADIO HORIZON	AT 2RH	AT 3RH	AT 4RH
BAND ONE	0 dBmV	-15 dBmV	-21 dBmV	-24 dBmV	-27 dBmV
BAND III	0	-17	-23	-26	-29
BANDS IV/V	0	-19	-26	-29	-32

NOTE: Losses shown do NOT include ALL over horizon degradations; see text.



Average scatter signal levels as time of day and period of year (light/top Nov-May; bottom/dark May-Nov). 0 is 0 dB median level. Note average winter levels down, peaks earlier in day than summer.

hundreds of slightly-different-length paths can co-exist between your receiver and the distant transmitter.

If you understand the problem, you may be better able to apply the solutions.

WHY AT UHF?

The various ingredients for extended range reception, via (tropospheric) scatter, all come together in the UHF television frequency range. They are:

1) The scatter itself. While present at VHF, and even into the SHF range (i.e., beyond 3,000 MHz), there is a slight frequency (megahertz) curve which peaks in the 500-1,000 MHz region.

2) Low noise receive front ends. As detailed in Tech Bulletin 9302, ultra-low-noise front ends (i.e., at the masthead amplifier) are seldom useful in the band I and III regions (because of manmade and atmospheric noise imposed thresholds). But at UHF, especially in a non-industrial area, you really can see the improvement a 0.5 dB noise figure makes.

3) Antenna gain. Antenna gains in the 17 dB and up range are possible at VHF (see table page 9) but may require such elaborate mechanical mounting schemes that the structures are difficult to handle. At UHF, whether stacking multiple yagi antennas into an array, or, building a suitable parabolic dish, it is simply more manageable.

4) Lack of co-channel. As long as the UHF spectrum does not become overcrowded, co-channel interference should not be a major problem (see TB9301). If you elect to install an antenna array that works in the scatter realm, you will probably select between a large yagi array or a parabolic. One of the pluses in favour of the parabolic choice is the exceptionally clean antenna 'pattern' (lack of side and rear lobes; see TB9302). That translates into less co-channel pick-up; a plus you will not have with a large stacked yagi array.

When studying the first table (page 9) it might also be useful to consider just how physically large the composite array will be to accomplish the various gain levels quoted.

Array size is show in the table on page 10 ; gain comes at a price, the array size becomes physically large quite quickly! How large depends upon the frequency and the type of antenna. In our top example (band I, eight 5 element antennas) the individual yagis are stacked 4-wide by 2 high; an 'array' that ends up being 28.25 metres wide and 4.97 metres high. The same 4-wide by 2 high array at channel 11 is 5.68 metres wide by 2.8 metres high. And at channel 27 (band IV) 2.17 metres wide by 1.61 high.

Note just for comparison that in the physical space required for a 4-wide by 2 high channel 1 array of 5 element yagis you could place:

COMPARISON OF ANTENNA GAIN

There are two basic gain-building blocks available at VHF; the five element yagi at band I and the ten element yagi at band III. At UHF, although some manufacturers claim gains of 18 dB+ for multiple-element yagi type antennas, their true gain seldom exceeds 12 dB for 20 elements in the lower UHF band; 14 dB at the higher UHF channels. Our comparison therefore uses **7.0 dB** for a 5 element **band I**, 10 dB for a 10 element band III and **12 dB** for a 20 element **band IV** antenna in this table as gain-bench-marks.

FREQ.	REF. ANT.	2X	4X	5' Dish	8X	7' Dish	16X	10' Dish	20' Dish	32X	30' Dish
BAND I	7.0 dB	9.5	12	NG	14.5	NG	17	NG	NG	19.5	NG
BAND III	10.0 dB	12.5	15	NG	17.5	NG	20	NG	(14)	22.5	(15.5)
BAND IV	12.0 dB	14.2*	16.4	13.5	18.6	15.5	20.8	18	20.5	23	22
BAND V	14..0 dB	16.2*	18.4	14.5	20.6	17	22.8	19	21.5	25	23

NG indicates antenna does not have useful gain at the frequency specified. Gain increases 2.5 dB each time the overall antenna size is doubled (i.e.., **2X** is two times one bay, 4X four times one bay); for VHF antennas. /* In bands IV and V, gain increases 2.2 dB for each doubling to allow for cable-phasing-line losses at the higher frequencies (see TB9302). Finding and using properly designed 10 element band I yagis will increase all band I dB gain numbers by 2.5 dB (i.e., 32X becomes 22 dB [gain]). All antenna gains reference **dipole**.

a) 80 ten element channel 11 yagis

b) 144 20 element channel 27 yagis

Such are the effects of wavelength on physical size.

Note also that in the gain department (above), an array of 32 (4-wide by 8 high) channel 27 yagis with 23 dB of gain compares favourably with a 30 foot parabolic dish (22 dB of gain).

But there are considerations other than sheer gain.

1) Cost. Depending upon your ability to fashion parts with your own hands, a 30' dish should cost between $500 and $1,000. An array of 32 yagis (20 elements each) around $2,100 for the antennas, the signal combiners (10 four way splitters, 1 two way) another $75 plus the 11-foam series cable for the phasing harnesses, with fittings. Then you will need some form of metal support structure on which to install the 2.17 metre wide by 11.27 metre tall array. All told, from 2+ to 3 times as much money as the parabolic.

2) Complexity. The yagis win here; the first time you build a sizeable parabolic will be a learning curve; you already know how to take yagis out of the box and assemble them! On the other hand, if someone in New Zealand were to start offering 'assemble-your-self' parabolic kits, it could be a close comparison.

3) Performance. That 1 dB difference could go either way; the parabolic gain number (22 dB) assumes the builder will give away at least 2 dB with mechanical errors. The yagi array, on the other hand, requires careful and identical positioning of the phasing lines for each antenna; there is no room for wham-bam-thank-you-mam assembly here.

4) Mechanical rigidity. If the antenna site is wind exposed (as most are), the yagis have the advantage; assuming you don't cut corners with the mechanical support system for the antennas. The roll-your-own parabolics will survive 100+ kilometre winds and even 1/2" radial ice loading but only if carefully front and rear guyed.

5) Errata. A 30' dish is capable of creating 17 dB of gain at channel 11 (15.5 at channel 4) at the same time it is producing 22 dB at channel 27. The dish has a single focal point; i.e., all signals (regardless of their operating frequency) focus to a centre point in front of the dish. This means you can take-off the dish with appropriate feed antennas several different channels simultaneously; even at bands III and IV/V simultaneously.

This does require some special attention to

DECISIONS RELATING ANTENNA SPACE REQUIREMENTS vs.GAIN

ANTENNA TYPE	GAIN ref dipole	ANTENNA LAYOUT PATTERN	Metres W X Metres H
		ANT ANT ANT ANT	
B-I/5 EL. Ch.1			**28.15 x 4.97**
8X	14.5 dB	ANT ANT ANT ANT	
16X	17.0 dB	ANT ANT ANT ANT	
		ANT ANT ANT ANT	
			28.15 x 14.90
		ANT ANT ANT ANT	
		ANT ANT ANT ANT	
32X	19.5 dB	ANT ANT ANT ANT	
		ANT ANT ANT ANT	
		ANT ANT ANT ANT	
		ANT ANT ANT ANT	
			28.15 x 34.78
		ANT ANT ANT ANT	
		ANT ANT ANT ANT	
		ANT ANT ANT ANT	
		ANT ANT ANT ANT	
B.III/10 El./Ch.11			
8X	17.5 dB	See 8X above	**5.68 x 2.80**
16X	20.0 dB	See 16X above	**5.68 x 8.40**
32X	22.5 dB	See 32X above	**5.68 x 19.60**
Band IV			
5' Dish	13.5 dB		**1.53 x 1.53**
7' Dish	15.5 dB		**2.14 x 2.14**
8X/20 El.	18.6 dB	See 8X above	**2.17 x 1.61**
10' Dish	18.0 dB		**3.05 x 3.05**
16X/20 El.	20.8 dB	See 16X above	**2.17 x 6.41**
20' Dish	20.5 dB		**6.11 x 6.11**
32X/20El.	23.0 dB	See 32X above	**2.17 x 11.27**
30' Dish	22.0 dB		**9.16 x 9.16**

TEN OF THIRTY-TWO YAGIS ARE VISIBLE IN THIS PICTURE; TASO GRADE 1 / 200 km

the design of the feed antenna; that's a caveat, not an impossible hurdle.

So if you have a situation where you could benefit from a 15.5-17 dB gain antenna at band III, and, a 22 dB+ gain antenna at bands IV/V and it could be the same basic antenna, well, that makes the parabolic a clear winner in the choice department. Note that a 15.5 to 17 dB gain antenna at band III is the equivalent to 4 or 8 ten element yagis in this band.

And finally, if a 30 foot parabolic is good, what about a larger dish?

HOW BIG CAN YOU GO?

The construction technique to be outlined here for roll-your-own parabolics is suitable for sizes to 40 feet (12.21 metres); subject to your own abilities to make it wind proof. Hundreds of identical dishes have been built from the same plans you will follow and many have survived in high-risk locations for ten years or more. And there is a high percentage of wood in the design; something that suits New Zealand builders well.

Beyond 40 feet, while the plans will allow antennas as large as 60 feet, neither the construction materials nor your construction abilities advise this. It is worth mentioning however a modification of the parabolic known as the 'Half-Bolic', capable of gains in the 30 dB region (bands III, IV and V), overcomes the structural problems of the full-parabolic to be described here (*).

WHY BIG ANTENNAS WORK

Any VHF/UHF reception beyond

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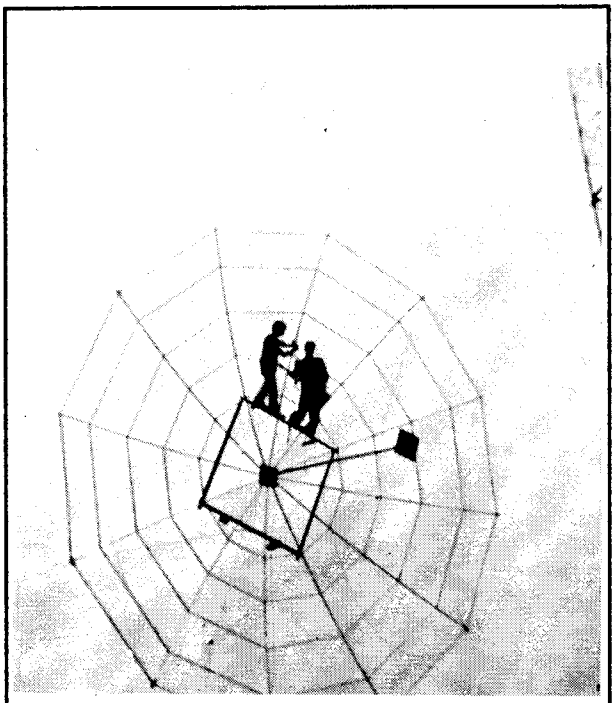
*/ **Half-Bolics:** Analysis and Construction Details. A 25 page report available (copy). Everything you need to know to duplicate. Order HB-001 at $15; see page 38 here.

/ **LaPORTE RHOMBIC: Analysis and Construction Details. A 15 page report available (copy). Rhombics are a particular mechanical challenge for vertically polarized signals at band I; very suitable for gains to 28 dB at bands I, III. At UHF, such gains are possible but mechanical rigidity problems considerable.Order LP-001 at $10; see page 38 here.



40' PARABOLIC/ BEING LIFTED 32m UP

line-of-sight relies on some form of scatter propagation except when there is lower atmospheric bending (i.e., enhanced signals correlated with periods of fine, mild weather, such as just preceding a weather front). This includes the region from visual horizon to radio horizon as well; our familiar 'fringe service' area.

It is the nature of scatter that two or more pathways co-exist between the transmitting antenna and the receiving antenna. Large antennas (whether long-large, or stacked-large or both) help to compensate for this multi-path effect by their sheer size.

Within line-of-sight, signal variations are stable-in-place. Take an antenna, connect it to a field strength meter and find a good signal. Mark the ground where the signal is good and then move the antenna a few feet left or right, closer or further to the station until you find a spot where the signal is weaker. Mark that spot.

Go back a day, week or month later and you should find the two marked spots still identify high and low signal level points.

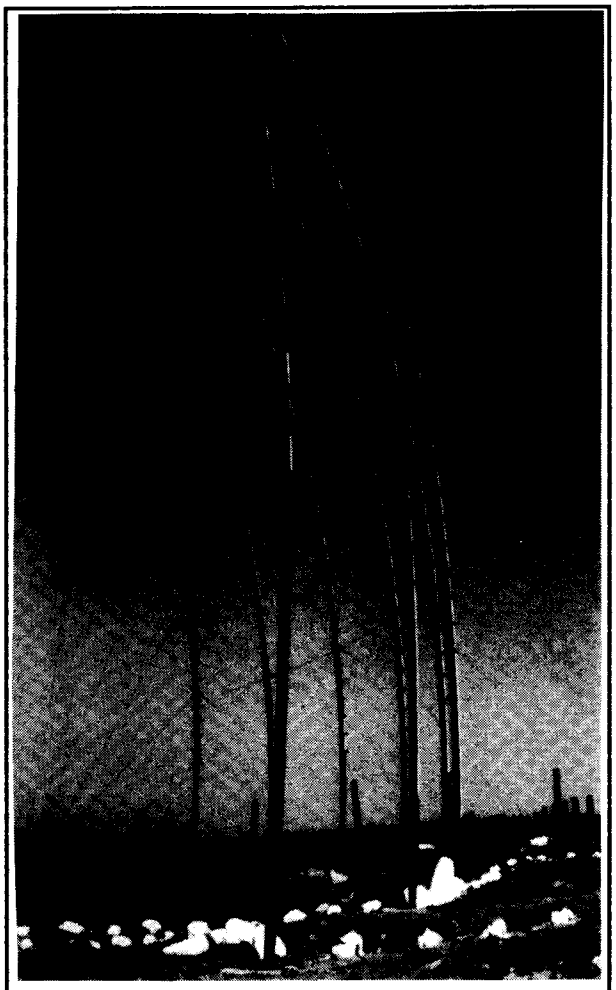
Now take the antenna and FSM to a point outside of the radio horizon; repeat the test marking the two spots. Now, unless the low spot is shielded (by a building, tree), if you go back an hour, day or later it has probably changed on you. Checking the high signal spot, you may find it has also moved.

From the visual horizon zone outwards, the signal levels are greatly dependent upon the nature of the scattering medium at the time of measurement. If the test receiving site is not foreground blocked by shielding, the measured signal level varies randomly over time.

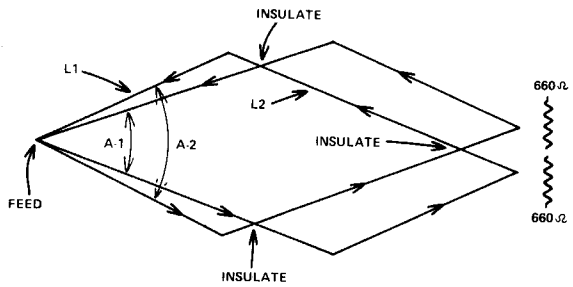
A physically large antenna array occupies more space than a small antenna.

By occupying more physical space (i.e., portions of two or more wavelengths either in-line, up/down or left/right), the antenna is inside two or more physical regions.

The scatter signal varies over space, randomly. It is 'hot' here one minute, 'hot'



HALF-BOLIC/BIG IN PERFORMANCE



LaPORTE RHOMBIC/ ONE OF SEVERAL COMPLEX WIRE ANTENNAS POSSIBLE

there a minute later. As you go further out into the scatter zone (i.e., further and further from the transmitter) the movement of 'hot' and 'cold' signal spots occurs more frequently. In other words, on a small antenna at the radio horizon the signal fades slowly enough that you can 'see' the fades, over time. At the 2RH range, the fading is so rapid and 'choppy' the video and audio seem to be fading independently of one another. At the 3RH range, the fading appears to be tearing up the individual picture segments and the audio may be garbled.

The answer to these problems is to make the antenna larger; make it occupy more space.

Why?

The solution to this problem hinges on having at least some of the antenna where the signal is, when it isn't where it was a minute (second/millisecond) ago. This requires the capture area of the antenna to be large, as a function of the wavelength and physical space. Large can be in line (as in many elements on a single boom) or it can be large as in frontal area (having two or more stacks of antenna in an 'array'). When the signal fades out (for however briefly) on one part of the antenna, it is still present on other segments of the antenna.

Small capture area antennas have low gain in the radio horizon area, and beyond, because they are simply 'out of signal' a sizeable percentage of the time.

Beyond the horizon (line of sight) is just that simple. Well, almost. Additionally, as the signal spreads out (i.e., a given amount at the transmitter spreads thinner and thinner as it moves away from the transmitting aerial), the available signal is diminishing, also. Thus we have the worst of two worlds:

1) The signal fading has increased, and,

2) The signal level has decreased.

Increasing the antenna capture area, and at the same time the gain, improves both of these conditions.

DEALING WITH THE FADING

A signal that fades alot is not much good, of course. 'Differential fading' (where the video and audio fade at separate times) is even more bothersome.

The standard TV set has an automatic gain control (AGC) circuit, usually capable of handling (smoothing out) fades of 10 to 15 dB. The AGC range (or window of fading it can handle) is less of a problem than the time constants built into the AGC network; i.e., how long after a fade starts does it take the receiver to respond with more gain, and, how long after a fade stops does it take for the receiver to respond with less gain.

The installer will find certain models of some brands have fast acting AGC; others are far too slow to cope with scatter range signals. If you are aware of receivers which handle 'airplane flutter' (signal variations caused by an airplane providing a signal reflection point as the plane flies along the path between you and the transmitter), chances are the same receiver will handle scatter 'flutter' as well. There are other answers; and they cost money.

Early on in planning a RH/2RH/3RH receiving system you must decide what you will do with the received signal(s) once they are coming out of the antenna array. If, for example, they are UHF; will you leave them on UHF for transport to the receiver(s)? There are sound arguments for converting UHF to VHF at the antenna.

a) Cable loss. We are already aware that coaxial cable (or open wire line) losses increase as the frequency increases (see

WHAT TO EXPECT WITH 2RH and 3RH VHF SIGNALS

If you arrive at a site, set up a 7 element band I-III home antenna and a battery operated TV set and find weak (drifting in and out) frame bars on the desired (distant) channels, it can be difficult to imagine how much things will change with proper antenna gain and a low-noise masthead amplifier. Here's a guide.

ANT SIZE	ANT GAIN	LOW NOISE MASTHEAD	MEASURED VCF LEVEL/*	DESCRIPTION OF RECEPTION
7 EL. Test	< 6 dB	NO	Cannot	Drifting in-out frame bars; occ. sync lock
7 EL. Test	< 6 dB	YES	< -30 dBmV	Frequent sync-lock; heavy fading
10 EL.	10 dB	YES	-30 dBmV	Improved definition, still barely Grade 6
2X 10EL.	12.5 dB	YES	-27.5dBmV	Grade 6; fading annoying
4X 10EL.	15.0 dB	YES	-25.5 dBmV	Decent detail (Grade 5); still some fading
8X 10EL.	17.5 dB	YES	-23 dBmV	Grade 5; fading now occasional
16X 10EL.	20 dB	YES	-20.5 dBmV	Grade 4; fading now very occasional
32X 10EL.	22.5 dB	YES	-18 dBmV	Grade 4; almost no fading (1X every 5 mins.)
64X 10EL.	25 dB	YES	-15.5 dBmV	Grade 3; fading now 1X every 30 minutes

If the same site were to install a Half-Bolic antenna with 30 dB gain on band III, the results would be:

18.3m X 36.6m				
Half-Bolic	30 dB	YES	-10 dBmV	Grade 3+; fading now 1X every 6 hours

*/ Measured VCF (video carrier frequency level) does **NOT** include (typically 20 dBg) masthead amplifier gain.

TB9302; page 22). If your total line length between antenna and the last receiver exceeds the amount of amplifier gain practical in the transmission line you have chosen, you have two choices:

1) Select a higher grade (i.e., larger) transmission line, with less loss, or,

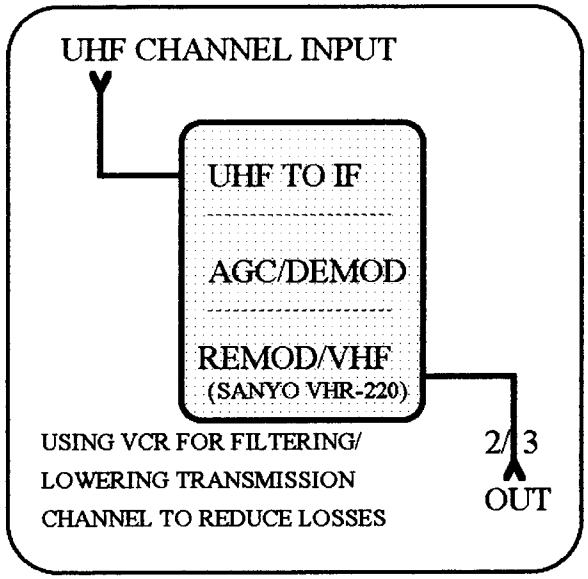
2) Down convert the UHF channels to VHF where cable losses are lower.

b) Applying AGC. The direct-off-antenna (after pre-amplification) signal(s) can be AGC'd separately from the TV set's AGC but it is done better at VHF than at UHF. AGC ranges of +/- 20 dB from a specified input for +/- 1 dB output variation are typical in single channel AGC amplifiers.

c) Adjacent channel filtering. You may find the distant UHF channel you need is within one or two channel(s) of a much closer UHF station and separating the two is a problem.

By down converting the UHF(s) down to VHF, the non-desired signal can be run through a bandpass filter on the selected VHF channel. Bandpass filters at VHF are capable of removing non-desired lower, upper (or both sides) adjacent channel signals as much as 40 dB stronger than your desired signal. Such filters do not exist at UHF.

If you have (or can place) commercial mains power at your antenna site, another down conversion + adjacent channel filtering system can be considered. Some (carefully selected) home VCRs have unusually good adjacent channel selectivity. The Sanyo VHR-220, for example, offered at discount for around $500, works very well in removing a weak signal (range of 40 to 50 dBuV) from adjacent to a much stronger signal (range of 75 to 90 dBuV). If you input the Sanyo on the weaker distant channel, outputting through its (channel 2 or 3) modulator, you have perhaps solved two problems in one step; getting out from under a strong adjacent channel, and, placing the distant (UHF) signal on a band I VHF channel for line distribution



HOW MUCH IMPROVEMENT WHEN MASTHEAD NOISE FIGURES DROP?

When a properly designed masthead is carefully installed, the lower noise figure of the masthead amplifier becomes the NEW noise figure for the full receiving system. A typical UHF TV tuner, the 'front-end' of the TV set, has a noise figure of 10 dB. If you place a 3 dB, 2 dB or 0.5 dB noise figure masthead at the antenna, the new system noise figure will match the masthead; a direct improvement of 7 dB (for 3 dB nf), 8 dB (for 2 dB nf) or 9.5 dB (for a 0.5 dB masthead amp). **But can you see it???**

TV TUNER nf	Masthead nf	Net Improvement	Net Improvement Equal To:
10 dB	5 dB	**5 dB**	Making antenna 2 times as large
10 dB	3 dB	**7 dB**	Making antenna 2.8 times as large
10 dB	2 dB	**8 dB**	Making antenna 3.2 times as large
10 dB	0.5 dB	**9.5 dB**	Making antennas 3.8 times as large

NOTES: Sources at BCL suggest some (the best of the best) newer TV sets have UHF tuner noise figures as low as 6 dB; and tuners in some high-end VCRs also have 6 dB UHF nf . Most remain closer to 10 dB.

as well. This approach is far less costly than selecting UHF to VHF converters and then following them with AGC strip amps and bandpass filters.

And the fading? There is an interesting threshold that takes place. When the antenna is just plain 'small', you are not even aware the distant signal is 'there'. On a larger antenna, you can detect the signal but it has heavy fading.

In a couple of size 'ups' the signal level becomes enough for Grade 5 viewing but the fading is disruptive.

And the threshold. As the antenna array grows larger the average signal level grows by amounts to be expected with forward gain increases. The fading, however, drops down to very manageable levels as you begin to place enough frontal capture area before the wave to fill in for those 'low' spots. A table on page 16 suggests what you might expect .

UHF AMPLIFICATION

The selection of a 'best-available' low noise UHF masthead amplifier is important. As discussed in TB9302, GaAs-FET design UHF mastheads with noise figures as low as 0.5 dB are available. They are not in-expensive. To make a rational decision about the UHF masthead to use in a given installation, you need to consider what the difference is between a 0.5 dB noise figure and a less expensive 2.0 or 3.0 dB noise figure unit.

Unfortunately for the installer, masthead noise figure claims in literature are much like antenna gain claims; suspect. More importantly, unless you are prepared to install a test unit right-at the UHF antenna system terminals, there is no meaningful comparison you can conduct (such as on your workbench). See TB9302 for an explanation of how noise figures equate to masthead placement.

Bottom line? You build a relationship with mastheads (VHF and UHF) because you believe in their performance. Designs that stuff parts through holes in perf-board canNOT compare in performance to properly laid out circuits on G-10 or better printed circuit board.

Yet another table (top, this page) reduces to numbers what you can expect with changes (improvements?) in masthead noise figures. If your own results don't compare, first re-examine your installation techniques. Next, suspect the mastheads you are using are not delivering the noise figures claimed. You may be buying the wrong product.

WHAT TO EXPECT WITH 2RH and 3RH UHF SIGNALS

The **UHF** 'threshold', with a 0.5 dB noise figure masthead, represents the lowest signal level which can be detected in the TV reception industry; the result of the lower background noise at UHF. This means really weak signals can be found, built-up with antenna gain, and used; as much as 6 dB better than at VHF.

ANT SIZE	ANT GAIN	0.5 dB MASTHEAD	MEASURED VCF LEVEL/*	DESCRIPTION OF RECEPTION TASO GRADE	FADING
1X 20EL.	12.0 dB	YES	< -35 dBmV	6	Very Heavy
5' DISH	13.5 dB	YES	<-30 dBmV	6	Very Heavy
2X 20EL.	14.2 dB	YES	<-30 dBmV	6	Very Heavy
7' DISH	15.5 dB	YES	-30 dBmV	5	Very Heavy
4X 20 EL.	16.4 dB	YES	<-25 dBmV	5	Very Heavy
10' DISH	18.0 dB	YES	<-25 dBmV	5	Heavy
8X 20EL.	18.6 dB	YES	<-25 dBmV	4	Heavy
20' DISH	20.5 dB	YES	<-20 dBmV	4	Moderate
16X 20 EL.	20.8 dB	YES	<-20 dBmV	4	Moderate
30' DISH	22 .0 dB	YES	<-20 dBmV	4	Occasional
32X 20EL.	23 dB	YES	<-20 dBmV	3	Occasional
64X 20EL.	25.2 dB	YES	-20 dBmV	3	Very Occasional
60' X 120' (HALF-BOLIC)	30.0 dB	YES	-15 dBmV	2	1X / 30 minutes

*/ Measured VCF (video carrier level) does **NOT** include masthead gain (typically 20 dB); i.e., actual signal level from antenna cited, **before** amplification.

Now let's translate the anticipated results to a 0.5 dB noise figure GaAs-FET (ultimate) masthead. The table above does that.

Once you have sorted out masthead gain and noise figure and the cable loss between the antenna and masthead, the next problem is getting the signal to the TV sets. If the cable loss exceeds the gain of the masthead, can you re-amplify the signal along the line?

There is a bigger issue here; one detailed in TB9302.

1) The gain number of the masthead must be no less than 3 dB greater than the noise figure of the following 'stage' after subtracting line/split losses between the masthead and the tuner. If the tuner has a 10 dB noise figure, and the masthead has 20 dB of gain, you can lose 7 dB of signal between the masthead and the tuner and still have the masthead noise figure become the new system noise figure. Here's the math:

1) Masthead Gain/ +20 dB(g)
   a) Masthead nf/ [0.5 dB]
2) TV Tuner nf/ 10 dB
3) Gain required for masthead nf to become new system nf/ 10 + 3 = 13 dB [g]
4) Gain available for cable loss without affecting new system nf/ 7 dB [20-10 = 10; 10-3 = 7 dB cable loss]

At each stage between the masthead and the TV set, the (voltage) gain of the preceding stage must be no less than 3 dB more than the noise figure of the next stage.

With a 20 dB gain masthead, we could place a UHF line amplifier down the transmission line someplace between the masthead and the bottom of the line. We do this because if we don't re-amplifiy the UHF signal, the voltage arriving at the TV set tuner will be less than 13 dB (10 dB tuner noise figure + 3 dB voltage gain). Where do we place the line amp?

The answer depends, first, upon the noise figure (nf) of the line amplifier. UHF line-powered amplifiers are available (i.e., Fringe Electronics Ltd; model Cascade) which insert into the downline someplace between the (hilltop) masthead and the receiver(s) at the terminus of the downline. These amplifiers have:

a) A noise figure of their own

b) A recommended input level range or window

c) A maximum output capability

None of these factors can be ignored when selecting and installing line amplifiers (whether at UHF or VHF).

The Fringe Electronics model Cascade has an internal noise figure of 3.5 dB. The manufacturer suggests the following operating parameters be adhered to:

1) Minimum input: **+6 dBmV** (note how that correlates to the 3.5 dB nf; i.e.., 3.5 dB nf + 3 dB 'buffer' = 6.5 dB input).

2) Recommended input level: **+13 dBmV**

3) Maximum input: **+19 dBmV**

4) Gain: **23 dB**

5) Maximum output: **42 dBmV** (102 dBuV or 126,000 microvolts/126 millivolts)

6) Maximum number of amplified [TV] carriers through amplifier at maximum output: **4**

None of this should be confusing with the possible exception of 'maximum number of carriers'. All amplifiers have a maximum-rated-output; a (milli)voltage of signal level in the amplified frequency range. This is determined by the signal handling capability of the transistors in the amplifier. To exceed the output rating (i.e., trying to get +44 dBmV out of the amplifier in question) causes the transistors to overload; resulting in (rapid) signal degradation (video images cross modulate one another, and/or lose sync et al).

If the amplifier is rated at +42 dBmV maximum output, and it has 23 dB of fixed gain, the maximum input becomes simply:

a) Maximum output **(+42 dBmV)**

b) Minus gain **(23 dBg)**

c) Equals maximum input **(+19 dBmV)**

PLACING THE LINE AMPS

We need to compute:

1) The maximum likely output of the masthead amplifier

2) The minimum likely output of the masthead amplifier

This establishes the range of signal levels to be expected going into the downline. That in turn determines the range of inputs we will be coupling into the first line amplifier; not to be less than **+6 dBmV** and not to be more than **+19 dBmV**.

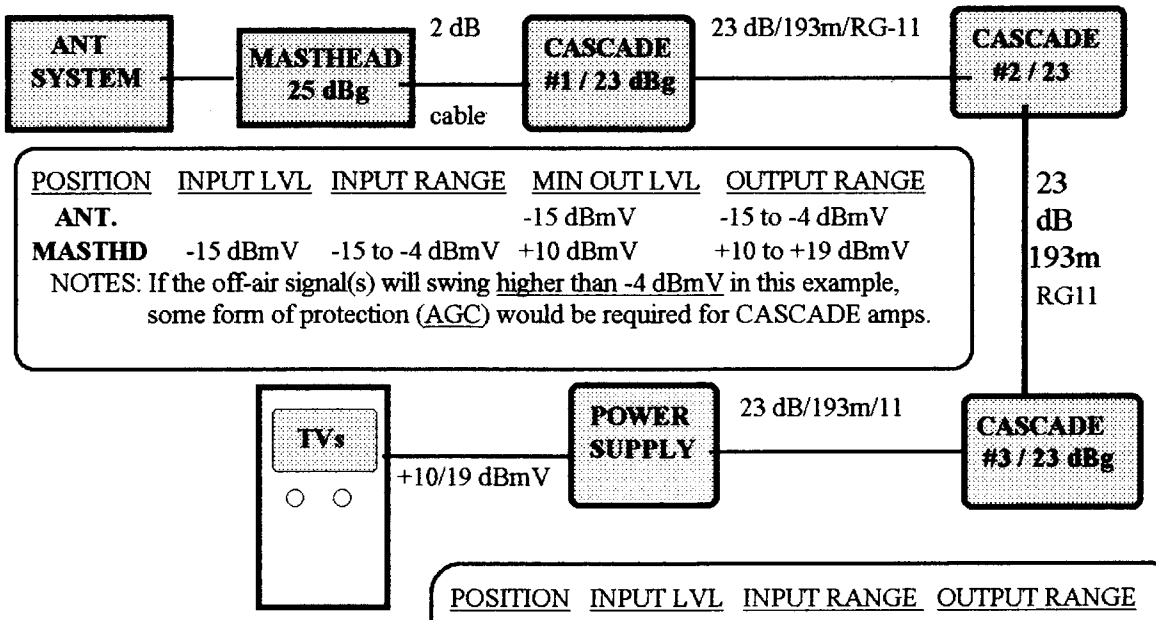
Then we need to compute the line loss per standard increment of downline. In our example we will use 11 Foam Series cable and the maximum frequency to be carried will be 750 MHz. Data sheets tell us loss in this cable at 750 MHz is approximately 11.9 dB per 100 metres. It is worth noting that at 750

WHAT TO EXPECT / BETWEEN GRADE 6 AND GRADE 4

GRADE 6/(-)32 dBmV/14 dB SNR/2X 20 EL

GRADE 4/(-)22 dBmV/24 dB SNR/20' DISH

PLANNING A UHF CABLE DISTRIBUTION SYSTEM



POSITION	INPUT LVL	INPUT RANGE	MIN OUT LVL	OUTPUT RANGE
ANT.			-15 dBmV	-15 to -4 dBmV
MASTHD	-15 dBmV	-15 to -4 dBmV	+10 dBmV	+10 to +19 dBmV

NOTES: If the off-air signal(s) will swing higher than -4 dBmV in this example, some form of protection (AGC) would be required for CASCADE amps.

POSITION	INPUT LVL	INPUT RANGE	OUTPUT RANGE
CASCAD#1	+8 dBmV	+8 to +19 dBmV	+31 to +42 dBmV
CASCAD#2	+8 dBmV	+8 to +19 dBmV	+31 to +42 dBmV
CASCAD#3	+8 dBmV	+8 to +19 dBmV	+31 to +42 dBmV

NOTES: To avoid overdriving (too much input) to CASCADE amps, keep inputs below +19 dBmV.

CABLE LOSSES:
1) MH to CAS#1 - **16.8m**/2 dB
2) CAS#1-CAS#2 - **193m**/23 dB
3) CAS#2-CAS#3 - **193m**/23 dB
4) CAS#3-P/S - **193m**/23 dB

Total Cable: 596 metres (1952')

MHz the loss in 7 Foam Series cable is about 15 dB per 100 metres (thus to save 3.21 dB of loss per 100 metres we select the 11 Foam Series).

Let's put all of this into a system diagram (see above).

Several points should jump out at you.

1) Even with 11 Foam series cable, cable loss at the mid to upper UHF channels is troublesome.

2) Because of the relatively narrow window through which the line amplifier functions (minimum input +6 dBmV; maximum input +19 dBmV; or 13 dB), we have to be concerned with strong UP fades that bring the antenna signals so high that the output of the masthead overdrives the input to the first (and succeeding) CASCADE amplifiers.

Another concern is the maximum rated output of the masthead amplifier although in this case we have plenty of 'headroom'.

3) Note that a common power supply sends 12 volts dc to the masthead and the 3 CASCADE amplifiers. In this example, the power supply must be capable of 98 m.a.; compute your own current load for any supply utilized.

The system is otherwise quite straight forward. The Fringe Electronics series of amplifiers use 'hard wiring' (i.e., the cable wires directly to the amplifiers; no connectors). And in case you missed it, three line amps in series is the maximum 'cascading-ability' of these amplifiers.

Options. Open wire transmission line is an option. It offers:

1) Lower loss per increment of length

2) More mechanical installation problems

Our amplifier to amplifier spacing (193 metres at 23 dB of 11 Foam loss) becomes 692 metres with 1" open wire line. That is certainly a plus since the loss in one amplifier

to amplifier span with open wire line is lower than all three spans in 11 Foam.

The downside is the mechanical integrity of the line. Where coaxial cable can be run at will (on the ground, loosely hung from — posts, etc.), open wire line requires support posts and protection from animals/stock. It also requires impedance matching transformers at the top and bottom, and going into and out of each amplifier location. The transformers need to be designed to pass power (up to 100 m.a. in our example system) and their loss (in converting 450 ohms balanced line to 75 ohms unbalanced) could be 2 dB or more at UHF. These losses cannot simply be ignored as the cumulative losses in our example system would be as high as 16 dB (8 matching transformers) between the output of the masthead and the input to the power supply.

THROUGH THE AIR

The commonsense way, even the urge, to do away with the interconnecting cable network between the remote antenna site and the typically-down-hill viewing points is understandable. The Radiocommunications Act and Radio Regulations as operated by the Ministry of Commerce, Radio Operations Group (ROG), allow some opportunities here

The rules allow you to retransmit, on-channel, UHF signals with a relatively-simple-to-obtain apparatus license, or possibly an exemption from licensing. The Act has different requirements for the 'commercial bands', operated under a management right, and the non commercial bands operated under an apparatus license. That's the good news. The bad news is that if you remain within the radiated power levels allowed (without more complicated licensing) you may have to do some fancy antenna work to cover much more than a 100 metres or so without wires.

The rules recognize there are situations where laying a cable or stringing a wire between where the signals are and where the receivers are is not always possible. Your receiving site may be 100 metres away from the antenna site, but a valley intervenes. And to cover that 100 metres you might need 700 metres of cable! We diagram an illustrative example on page 25 here.

Let's look at permissible power levels first.

1) The rules state you may retransmit, on the original channel, UHF signals. You may do this at a total power level of 50 dB below one watt (i.e., -50 dBw); e.i.r.p.

2) The rules are designed to insure you do not create interference with an on-channel 'booster' (that's what these devices are called; we'll abbreviate them OCB).

a) There is some confusion about whether or not it is possible to create 'interference' when you are outside of the TV station's secondary service area.

b) Each station has a map on file with RFS; a map which describes the total coverage area of the station. This coverage area is defined as so many microvolts of signal placed into an area. At band V, the coverage area is defined as going out to a point where the signal level (as measured) is 70 decibels greater than one microvolt per metre. In the real world this translates to around +5 dBmV (1,780 microvolts) on a test dipole at 600 MHz.

c) Some maintain that rules relating to interference cease to apply once you are operating outside of the station's coverage area. In fact, when an RFS office is called into a consumer location to check out poor reception (whether due to sloppy workmanship, interference or just plain weak signals) one of the first things they do is determine whether or not the complainer lives in an area which is inside of the station's coverage area. RFS/ROG literature clearly tells viewers requesting assistance:

> **"Where interference occurs within a recognised broadcast service area, no charge will be made for investigation** (of reception problems)".

However, when the complainer lives outside of a recognised broadcast service area, RFS/ROG advises:

> **"In a weak signal area it is not usually feasible to protect a broadcast signal,**

as even interfering equipment complying with the limits may still cause reception problems" [see footnote 20-1].

This means you may receive more leeway with an RFS inspector if your UHF OCB is located beyond the protected signal coverage contours of the TV stations.

-50 dBw e.i.r.p?

In measuring transmitter outputs (an OCB is a transmitter; no matter how low power it may be), 1 watt of power is assumed for measurement purposes to be 0 (zero) dB. That's not so unusual; 1,000 microvolts (1 millivolt) is assumed to be 0 dBmV in our world.

So a power level of - (minus) 50 dBw is simply 50 decibels below (lower than) 1 watt.

Power is measured at a known transmitter output impedance. In our world, virtually everything is 75 ohm impedance. Therefore in our measurements all of our power is referenced to power as measured at 75 ohms. This is handy because it allows you to use a standard TV field strength meter (FSM) to make measurements.

Some numbers.

a) 1 watt at 75 ohms impedance is the same as 8.6602 volts when measured on a TV FSM.

If your FSM doesn't go that high, don't despair. Place a 20 dB pad in the line and check for 866,020 microvolts (866.2 millivolts). With the 20 dB pad in line, they are the same.

b) The signal level you want is 50 dB weaker than 8.6602 volts. This voltage at 75 ohms is the same as +78.699 dBmV. So:

1) 78.699 dBmV
-50.000 dB
28.699 dBmV

2) So this says we can use OCB power as great as 28.699 dBmV to rebroadcast; yes?

Not quite; yet. The rules say "-50 dBw e.i.r.p." EIRP? That's the 'effective isotropic radiated power' business again; the same isotropic we ran into in TB9302 when discussing antenna gain numbers.

Recall the isotropic antenna is imaginary; appearing only on paper in mathematical formulae. In the real world we use a dipole as a reference antenna. So here's an adjustment to make; between a real world dipole, as a reference, and the imaginary isotropic source referenced in our rules-stated power limit.

The adjustment is 2.14 dB; you subtract it.

If the rules allow us to broadcast with an OCB using 28.699 dBmV of signal when the transmitter is connected to an isotropic antenna, in the real world we are allowed 2.14 dB less; 26.60 dBmV when we connect our OCB to a dipole.

Except of course using a dipole to transmit with our OCB isn't much more real world than the isotropic antenna. In the real world, we would connect our OCB transmitter to an antenna with:

a) Directivity (why transmit except towards where the viewers are located?);

b) Gain (which comes with directivity; see TB9302).

And this means ... we must use less power than +26.60 dBmV?

Right; now you are getting the scent of this bureaucratic trail! +28.74 dBmV OCB power is fine as long as you connect it to an isotropic antenna. Your next option is +26.60 dBmV to a dipole. For the real world, see the table on next page; 21.

HOW FAR CAN YOU GO?

If this is to be more than an amusing exercise in relayed signal voltages, you need the ability to cover some reasonable distances with the powers stated in the table on page 21. Of course you could go for higher power and license the OCB using a higher power licensing scheme; we'll discuss that separately.

What follows separates the skilled from the unskilled.

Footnote 20-1: See **Television & Radio Interference**, Ministry of Commerce PIB 9, Issue 1; June 1992.

REAL WORLD OCB POWER vs. TRANSMIT ANTENNA GAIN

TYPE TRANSMITTING ANTENNA	REAL WORLD POWER/dBmV	POWER/Millivolts	POWER/dBuV
Isotropic Source (see text)	+ 28.74	27.386	88.74
1/2 wave resonant dipole	+ 26.60	21.414	86.60
6 dB Gain Antenna	+20.60	10.732	80.60
8 dB Gain Antenna	+18.60	8.534	78.60
10 dB Gain Antenna	+16.60	6.880	76.60
12 dB Gain Antenna	+14.60	5.376	74.60
14 dB Gain Antenna	+12.60	4.274	72.60
16 dB Gain Antenna	+10.60	3.394	70.60
18 dB Gain Antenna	+ 8.60	2.696	68.60

NOTE: **Real World Power** is output power as measured at **input** to transmitting antenna.

1) You start with an on-channel UHF booster power equal to the maximum allowed by the table above. If you install a dipole antenna 10 metres in front of your selected transmitting antenna, the field strength can be measured.

a) This will measure the loss in free space between the front end of your transmitting antenna, and the dipole, at a distance of 10 metres (20 wavelengths at approximately 600 MHz). What will you find?

Approximately -16 dBmV/44 dBuV.

Now move the dipole 40 wavelengths (20m) from the front end of the transmitting antenna.

You will measure approximately -22 dBmV. Each time you double the distance between the front of your transmitting antenna and the receiving antenna, the signal level drops approximately 6 dB because path signal loss increases as the distance increases from the transmitting antenna.

The question of distance is simply a matter of dBs; decibels. We know:

1) How much signal can be radiated (a maximum of 26.60 dBmV ERP)

2) What the loss is for any distance we wish to calculate (see graph next page)

3) What the threshold of sensitivity might be for our ultimate receiving site (for example, assume a -46 dBmV threshold for a UHF TV tuner preceded by 0.5 dB noise figure masthead).

If we can radiate +26.6 dBmV, and our TV set is capable (with masthead) of detecting the presence of a video carrier at -46 dBmV, our 'window' is 26.6 + 46 or 72.6 dB. But our viewing customer wants more than the detection of a video carrier; he or she wants full colour television. From our TASO grading tables we know full colour begins with a signal + noise to noise ratio of 20 to 28 dB (see TB9302; pages 8, 27).

Assuming 28 dB SNR is our minimum goal, the -46 dBmV threshold is now -46 (plus) 28 dB or -18 dBmV. Our window of signal loss now falls between +26.6 dBmV (ERP radiated) and -18 dBmV (minimum signal level received) ; 44.6 dB total loss if we want TASO Grade 3 pictures as a minimum.

So how far can we go before we lose 44.6 dB of signal?

Not yet.

This is a transmission path. The path has:

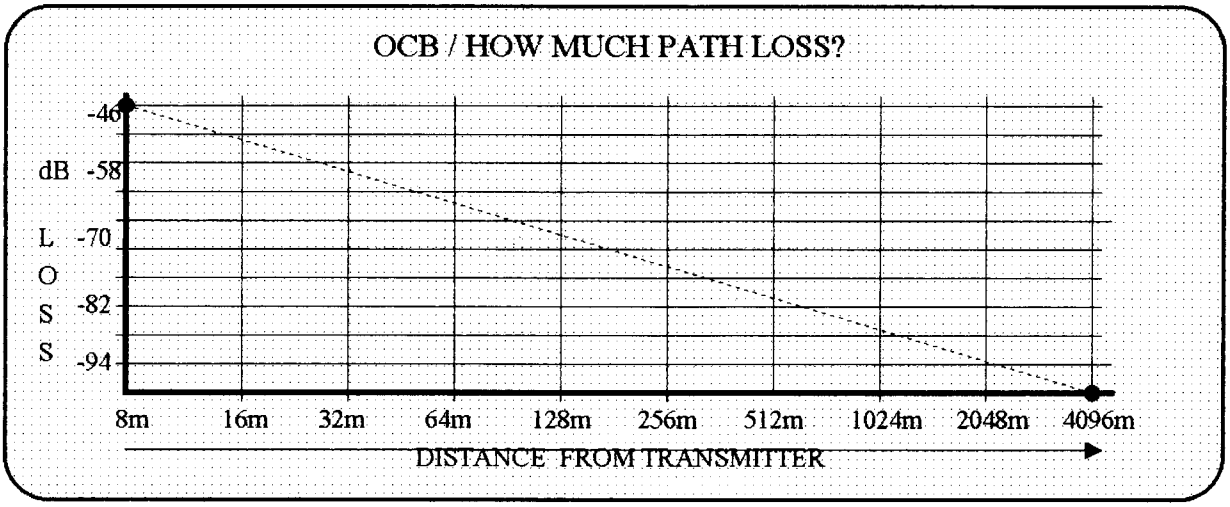
1) A known radiated power

2) A known (calculated) path loss

and

3) A known receive site gain factor.

If the path is made up of its various element gains and losses, gain at the ultimate receive site is also a factor. We have already set out a 'standard'; we will accept a signal + noise to noise ratio (SNR) of 28 dB. Granted, that is less than the 40 dB SNR of TASO Grade 1 but 28 dB SNR still remains a practical goal for first-time television. From that decision we found the path could have as much as 44.6



dB of 'space loss' (in the air between the transmitting antenna and the receiving antenna) and still produce our desired 28 dB SNR.

That overlooks whatever gain contribution as might come from the receive antenna at the ultimate receive site. If our receive antenna has 12 dB of gain (a typical 20 element broadbanded UHF yagi), this 12 dB is added to our available path loss; i.e., 44.6 dB becomes 56.6 dB of free space loss. (Or, if you leave the path loss at 44.6 dB, the 12 dB of receive antenna gain will raise the signal at the receiver 12 dB; 28 + 12 = 40 dB [SNR]. There's the TASO Grade 1 picture again.)

If receiver-site antenna gain helps the equation, how about a masthead at the receiver-site? Move to the head of the class.

Let us assume a 20 dB gain masthead at the receiver-site. Now our possible path loss goes up another 20 dB and becomes the original 44.6 dB + 12 dB receiver site antenna gain (56.6 dB) + 20 dB masthead gain (76.6 dB). Hummm. This could be interesting!

Is there more?

One more item. Loss; loss between the receiver-site masthead and the actual receiver. Whatever it contributes (say 6 dB or approximately 50 metres of Foam 11 at 750 MHz) has to come off the calculation. In other words, 76.6 dB minus 6 dB results in a total possible 'free-space-loss' of 70.6 dB for a resulting SNR of 28 dB.

So how 'far' is 70.6 dB of free-space-loss?

Approximately 128 metres (419 feet); see graph above. Not as far as you had hoped?

Recall this was with a 12 dB gain receive antenna at the ultimate receive site; and a 0.5 dB nf/20 dB gain masthead. Let's play with that a little.

If we increase the receive antenna size to 18 dB and change out the masthead, what happens?

1) Replace the expensive 0.5 dB noise figure/20 dBg masthead with a 2.0 dB noise figure, 25 dB gain unit. We lose 1.5 dB in threshold sensitivity but gain 5 dB in voltage. That's a net improvement of 3.5 dB.

2) The additional antenna gain is 6 dB so the combined gain is 3.5 + 6 or 9.5 dB.

What does that do to our distance?

From the graph above we see that if we improve the available path loss from 70 dB to 82 dB, our maximum distance spanned is now a bit less than 512 metres (1677 feet).

This would be a good place to restate what happens with free-space loss as the distance increases. Notice the free space loss between 16 metres and 32 metres; 6 dB. Now notice the free space loss between 512 metres and 1024 metres; still 6 dB. But the amount of space is far greater in the second jump than in the first.

Note the +26.6 dBmV is the effective radiated power, not the power from the OCB amplifier to the antenna. The dB gain of the antenna must be subtracted from the maximum output level of +26.6 dBmV (a

FREE SPACE LOSS - HOW FAR CAN YOU GO?

Loss in **free** (meaning not cluttered by buildings, trees, terrain) **space** is actually not loss at all; it is the natural result of your transmitted wave spreading out over an ever-widening pie-shaped piece of ground. Your transmitted signal is like a stream of water; if confined to a narrow channel (such as in a pipe) it retains its depth as long as the channel stays the same width. If the channel widens, the water spreads to fill the available space; and becomes shallower in the process. This is your transmitted signal, spreading out to fill the available space, getting shallower (weaker) as it travels forwards and spreads. To obtain maximum distance, you want your forward antenna **beamwidth** as narrow as possible at the antenna to restrict the spreading of the signal as it travels forward.

OCB ERP	DISTANCE OCB-RCVR	PATH LOSS/dB	RECEIVED SIGNAL LEVEL WITH: 12dBg Ant.	12 dB Ant. +25 dBg MH	18 dB Ant.	18 dB Ant. +25 dBg MH
+26.6 dBmV	8 metres	-46	**- 7.4 dBmV**	+17.6 dBmV	- 1.4 dBmV	+23.6 dBmV
	16	-52	-13.4	+11.6	**- 7.4**	+17.6
	32	-58	-19.4	+ 5.6	-13.4	+11.6
	64	-64	-25.4	- 0.4	-19.4	+ 5.6
	128	-70	-31.4	**-6.4**	-25.4	- 0.4
	256	-76	-37.4	-12.4	-31.4	**- 6.4**
	512	-82	-43.4	-18.4	-37.4	-12.4
	1024	-88	b/t	-24.4	-43.4	-18.4
	2048	-94	b/t	-30.4	b/t	-24.4
	4096	-100	b/t	-36.4	b/t	-30.4
	8192	-106	b/t	-42.4	b/t	-36.4

NOTES: Boldface (i.e., **-7.4 dBmv** above) indicates demarcation from 40 dB SNR [**TASO Grade 1**].
Underline (i.e., -19.4 dBmV) indicates demarcation from 28 dB SNR [TASO Grade 3].
In theory, if the OCB utilized a +40 dBmV amplifier output fed to an 18 dB gain transmit antenna, (+45.6 dBmV ERP) the TASO Grade 1 range would become just over 2,000 metres while the TASO Grade 3 would stretch to more than 8,000 metres.

number you can measure on your Field Strength Meter) to determine the actual output level permissible for the OCB amplifier.

The table above shows what happens when 12 or 18 dB gain ultimate-receive-site antennas, mastheads and no mastheads are juggled. This table suggests an ultimate range of approximately 1024 metres (with 25 dBg masthead) while maintaining the 28 dB SNR set out as a goal. In actual practice, installer-induced variables may reduce or extend this number by 50-200%.

AVOIDING FEEDBACK

An on channel booster (OCB) operates on the same channel (channels) for transmit and receive. Anyone who has placed a microphone too close to a speaker in a PA system knows about feedback.

This system can feed back. Precautions must be taken to ensure it does not go into self-oscillation (an oscillating OCB could also generate spurious signals outside of the UHF TV band and therein lies the potential dangers of the transmitter.).

Basically, no appreciable amount of the OCB amplifier output power should find its way back into the off-air receiving antennas. If it does, feedback (i.e., audio loop with microphone in front of PA system speaker).

This usually involves:

1) Crossing polarizations. If the incoming off-air signal(s) are horizontal, re-transmit on vertical. Or vice-versa.

2) Isolating the transmit antenna from the receive antenna. Put some ground (loss) between them; a brow of a hill, distance. The OCB transmit antenna should **not** be able to see (as in line-of-sight) the off-air receive antenna.

You connect the two together with low loss, well shielded cable (7-Foam, 11-Foam) but never unshielded line such as open-wire. The

masthead amplifier on the receive antenna, for example, through cable to the OCB output amplifier which ideally is mounted close to (right at) the re-transmit antenna(s) should be fed with coaxial line. We diagram it on page 25; note the OCB transmit site is hilltop (ground) 'shielded' from the off-air receiving site. If power at a remote site is a challenge, consider a small solar panel and battery. A typical masthead consumes less than 40 m.a. and a typical output amplifier (if needed) under 30 m.a.. For 24 hour operation, a solar panel and battery capable of handling around 2 amps per day is adequate.

Precise levels (to the transmit antenna[s] to stay at or under +26.6 dBmV) can be set with in-line fixed pads (3,6,10 dB etc.) placed between the OCB transmit amplifier and the transmit antenna array.

VARIATIONS

If your OCB site has viewers in two (or more) directions, you might consider two separate transmit antennas after the OCB amplifier; fed through a 2-way splitter. The rules limit you to +26.6 dBmV ERP in any single direction; or around a full 360 degree circle if your site warranted such a coverage pattern. With some careful antenna engineering, and use of 2/4/6/8 way splitters after the OCB 'output amplifier' the power output of the amplifier would be adjusted (with fixed pads) so no radiated signal level exceeded +26.6 dBmV ERP in any direction.

And in case it slipped by you, by employing wideband masthead amplification at the off-air receiving array, and, wideband amplification at the OCB transmit amplifier, you can re-transmit not just a single channel but the entire UHF bandwidth through the system.

OCB AMPLIFIER CHOICE

Recall that all amplifiers have certain parameters, including:

1) Correct (recommended) operating voltage (range)

2) A known amount of gain, within a specified bandwidth

3) A measured noise figure

4) A minimum recommended input

5) A maximum recommended output

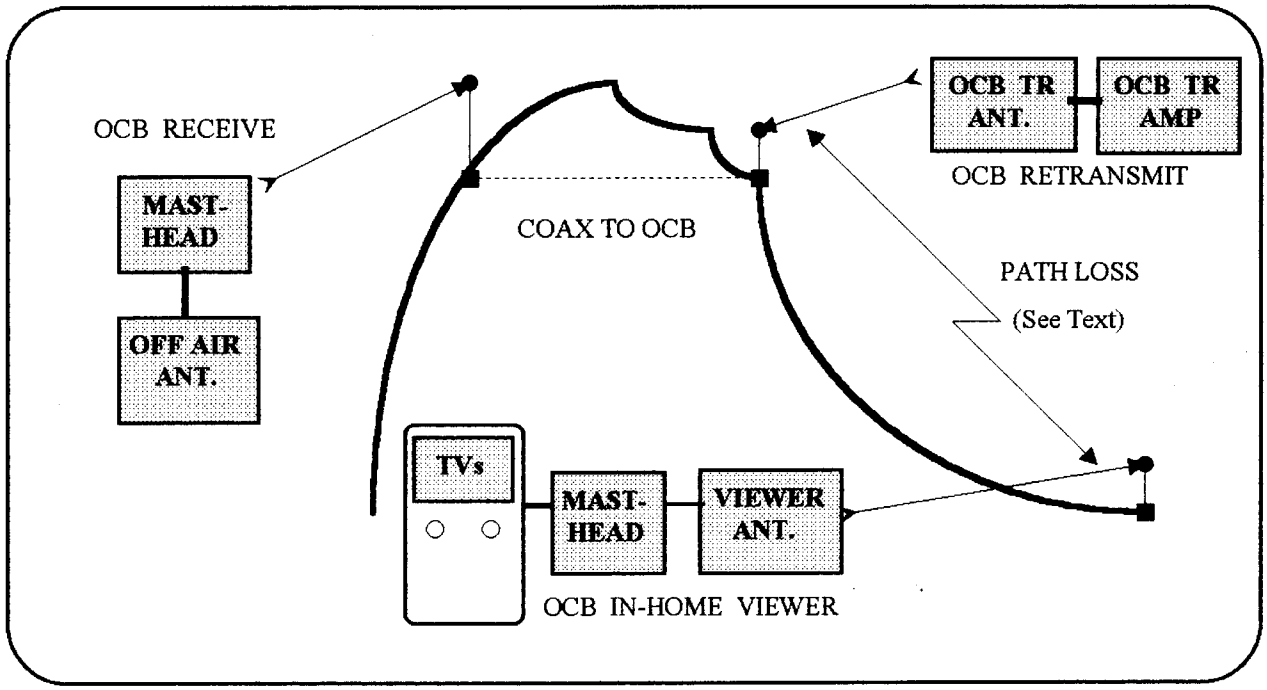
6) Specified input and output impedance

Adherence to all of these parameters is essential if you are going to obtain the amplifier performance claimed by the designer. The higher the operating frequency of the amplifier, the more critical precise adherence to the stated parameters becomes.

a) Voltage: Most amplifiers have diode regulation built-in; they expect a higher voltage supplied from the power supply than required for use. The higher voltage is (zener, other) diode regulated down to the design operating voltage. Too high a voltage is typically less of a problem than too low a supply voltage. When the supply voltage drops below the (diode) regulator turn-on voltage, the amplifier typically ceases to perform.

b) Bandwidth: Any signals you wish amplified must fall within the amplifier design bandwidth. Signals outside the bandwidth, if relatively weak, become weaker (i.e., the amplifier rejects them further, without gain). Very strong signals applied from outside the amplifier bandwidth can cause amplifier overload or generate spurious signals within the amplifier's rated gain-passband. If you have strange, trashy signals inside the amplifier passband, check the input for very strong out of passband signals.

c) The amplifier's noise figure is its threshold; the point above which it no longer contributes internal amplifier noise to the amplified signal product(s). To make a line amplifier (i.e., after the [initial] masthead unit) opaque to the signals, to ensure it contributes no degrading noise to the amplified output, always provide the amplifier with at least 3 dB more input signal than its own noise figure. If the noise figure is 5 dB, the input signal should be 5 + 3 or +8 dBmV. If the input is too low (such as +5 dBmV for a 5 dB nf), the picture is likely to look 'grainy'; that is, a fine background pattern of noise, not quite 'snow'



but detracting from a crisp, studio-quality picture. You are likely to notice this effect only on signals that leave the masthead at SNRs of 34 dB or more (i.e., TASO Grade 2 or 1); TASO Grade 3 and below are already corrupted with noise and the grain effect is buried behind the more pronounced off-air noise products.

4) Minimum Input: Related directly to the noise figure, as explained. Equally, there is a maximum input; a number selected to ensure you do not exceed the maximum output. If the amplifier has a fixed amount of gain (i.e., not user variable) and a maximum output, it follows there must be a maximum input. An amplifier with 25 dB of gain, and a maximum output of +45 dBmV cannot stand an input that exceeds +20 dBmV (45 - 25 = 20).

If the output rating is exceeded, the amplifier becomes a 'mixer'. When you see a faint picture drifting behind the primary video, that's cross-mod; the transfer of one set of video to the carrier of another. Unstable, drifting 'ghost video' appearing behind the primary signal is a sign of amplifier overload.

5) Maximum Output: As you can understand, related to the maximum input.

6) Input/Output Match: Coaxial cables and antennas have a characteristic impedance. The transfer of energy (from antenna to cable, cable to amplifier) occurs when there is a 'match' between the impedance of the two connecting parts. Most of our equipment is 75 ohms unbalanced. That's like placing a 75 ohm carbon (not wire wound) resistor across the terminals in question; in effect terminating the fitting with its own impedance.

Matching transformers convert one impedance (such as 300 ohm antenna) to another (such as 75 ohm coax). If the transformer expects 300 ohms at the antenna, but the antenna because of a design error is actually 100 ohms, there is a mismatch here. **Mismatch means lost energy.** Whatever signal level captured by the antenna, some of that signal is lost when the 100 ohm antenna is connected to a 300 ohm transformer. In this example approximately 50% of the original antenna signal voltage never makes it to the 75 ohm side of the matching transformer; it is lost in the 'mismatch' on the 300 ohm side.

Mismatch is about lost (never to be regained) energy (signal voltage). In really severe situations, mismatch can also cause ghosting of the video (a primary and one or more reflected images). Such ghosting is much more likely to be seen at UHF than at VHF (i.e., that ghost you are fighting may not be coming to the antenna at all; it could be in the antenna system itself from mismatch).

THE BIG ANTENNAS

Crucial to making full use of bands IV and V is the creation of unusually high amounts of antenna gain; whether for off-air reception, OCB transmitting and reception, or all of the above.

We already know that large antenna arrays can be created by 'stacking' (i.e., phasing together) two or more identical antennas with known characteristics. Tables here (see pages 9, 10, for example) describe arrays of up to 64 identical yagi antennas.

But, as noted on page 9, big arrays utilizing commercially built antennas cost big bucks; for the antennas, the support structure and the 75 ohm combiners needed to phase the individual antennas into a single feed-point array.

There are three contenders for the non-commercial-antenna system:

1) Large Rhombic (such as LaPorte design rhombic); offering up to 28+ dB gain;

2) Full parabolic, with sizes to 40 feet practical, and offering gains to 25 dB;

3) Half-Bolic with sizes to 60 feet high by 120 feet wide offering gains up to 30+ dB.

Detailed how-to-do-it construction articles are available from this source (see page 40) for all three antenna systems. Each, however, assumes you are approaching the selected antenna with a practical understanding of how each works and what degree of precision each design requires if it is to provide you with the same gain its designers achieved.

First these warnings:

1) None of these antenna designs is suggested for people who are not handy with their hands. Each requires creation of customized parts/pieces to tolerances of a few mils. None require a full machine shop; all require a degree of dedication to precision workmanship.

2) Each of these designs is physically large. This translates to reasonably significant wind loading (especially for the full-parabolic and Half-Bolic) and there is a world of difference between building it one day and having it still functional one, three or five years hence.

3) No hard costing estimates can be given for any of the designs. We did take a full BOM (Bill of Materials) to national chain Placemaker for a 30 foot parabolic and less the metal plates they came back with a $570 estimate. The Half-Bolic and Rhombic antennas are less able to advance-cost because of the type of parts involved.

4) Nor can any hard estimate of manpower-hours be given here. We do know from several hundred previously-built examples approximately how many man hours are in each antenna and we share that information with you. You could be 50% lower if you are very handy, or 100% longer if you are slow and tedious.

None of these designs is for the faint-hearted. These are all serious antennas for serious endeavours. If you approach the commitment to building any of these designs with the weakness that you can cut corners (thereby changing the structural integrity of the final antenna, or, reduce its dimensional accuracy's), please don't contact us with a letter complaining:

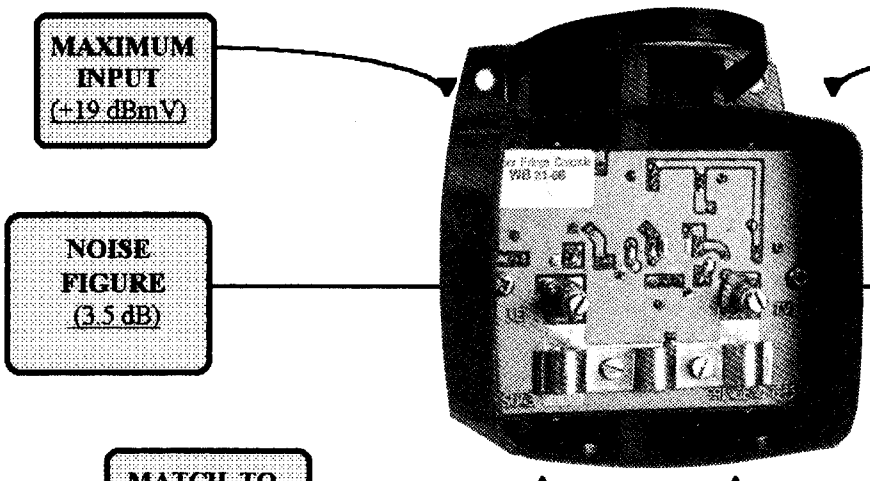
"We built it just like you said ... **except** ....".

because the first time you degrade the antenna's structural integrity, or, its surface accuracy's, you have just degraded as well the antenna's performance.

THE LaPORTE RHOMBIC

Of the three, this is the nearest thing to extremely narrow beamwidths you can build or buy. This says the antenna must be dead-on the transmitting station (within a couple of degrees maximum error), and, you will have the ability to fine-tune the array after installation to knock down (if not out) any co-channel sources.

A LaPorte Rhombic is a multiple-wire rhombic; similar to stacking a pair of yagi antennas to pursue narrow receiving beamwidth patterns. The antenna uses support poles (60' plus are adequate for VHF bands I and III; higher is not necessarily better!) and the antenna is in the form of a rhomboid; kind


MAXIMUM INPUT (+19 dBmV)
OUTPUT CAPABLE (+42 dBmV)
NOISE FIGURE (3.5 dB)
MINIMUM INPUT (+6 dBmV)
MATCH TO CABLE (75 Ohms)
OPERATING VOLTAGE (12 v.d.c.)

ANATOMY OF AN OCB AMP

(Illustrated: Fringe Electronics Cascade)

of like a diamond shape. This presents a problem for vertically polarized signals at band I since the antenna is approximately 1/3rd as high as it is long and achieving the necessary height for vertically polarized band I requires poles closer to 100'+ than 60'+. At band III, vertical polarized signals are more manageable (still requiring poles 50'+). At bands IV and V, the original 60' poles for horizontal will also do for vertical.

The LaPorte Rhombic is basically strong wire (copper clad steel for example), insulators, and, some support structures. The wire is of specified lengths, and wire to wire dimensions. The impedance of the antenna is high (600 ohm region) and balanced; matching transformers or matching lines are required to couple into 75 ohm unbalanced equipment/lines. The performance of the antenna depends upon your ability to hold the structural integrity stable within a few centimetres at all times, and your skills to 'tweek' its direction of pointing after installation.

If you have access to the support poles (or towers), this antenna is the least expensive way to get 25-28 dB of gain at bands I, III, IV or V. The antenna is reasonably forgiving of frequency excursions; if designed for band I, for example, it will operate with acceptable performance on band III provided the band I and III stations are coming from the same transmitter site.

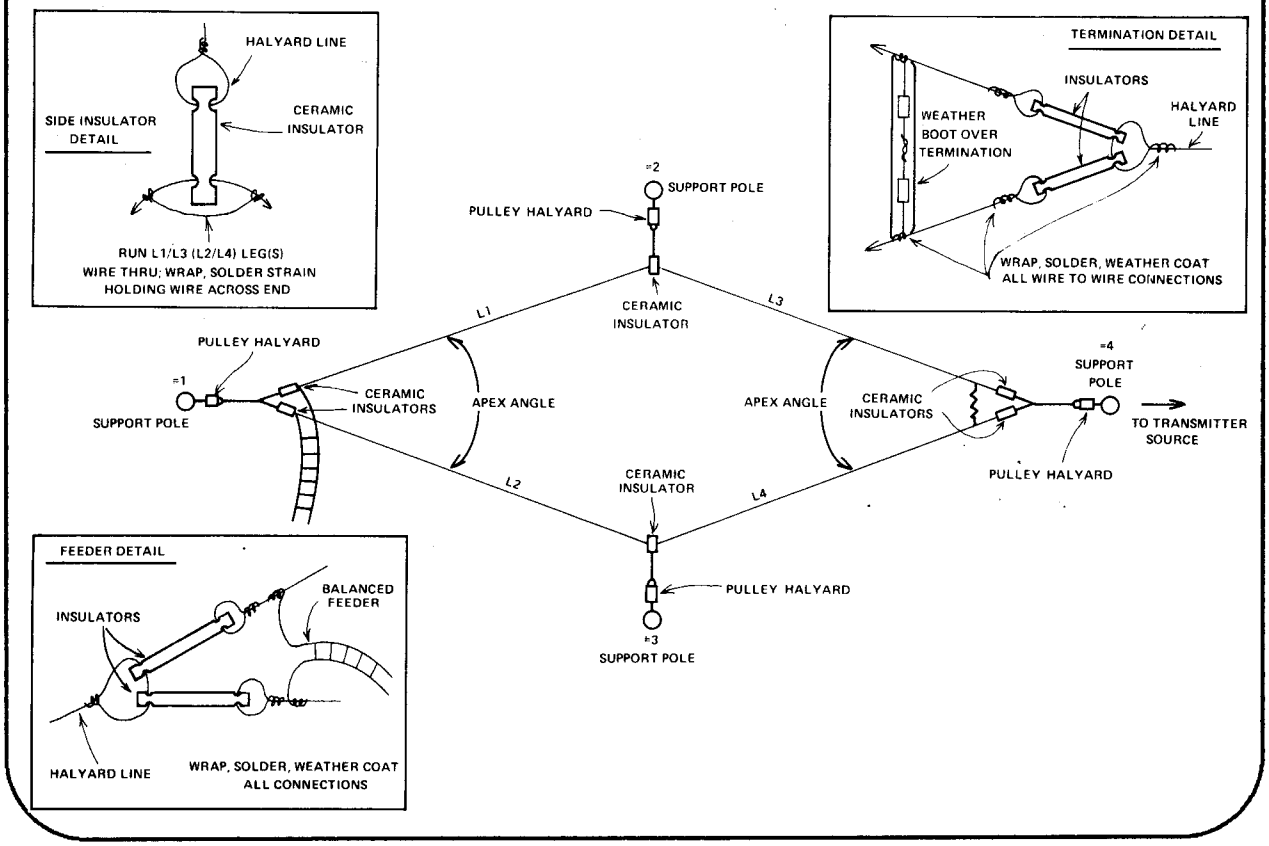
In the after-construction 'tweeking' process, you can tune-out co-channel interference better with the LaPorte (or other sub-design) rhombic than with any other antenna known. But, in tweeking a rhombic, patience is an important virtue and it needs to be done over time to allow a variety of on and off-path weather conditions to intercede.

a) Probable cost: $400 VHF to $150 UHF less support poles/towers.
b) Probable construction time: 12 to 30 man-hours less support poles/towers.
c) Probable 'tweeking time': two to five days at 2 hours per day (to accommodate changing reception conditions).

THE HALF-BOLIC

This antenna is the most costly, but the least complex, of the three choices. Basically, it is a huge screen reflector, curved like a segment of a parabola, and mounted on the ground. Its height (as described in our analysis; other sizes are scaleable) is

BASIC RHOMBIC CONSTRUCTION (from plans available)



approximately 60 feet and width 120 feet. The backbone of the support structure requires eight (8) welded-steel tubular poles set into concrete. At 60 feet high each, the steel poles are 'stressed' by pulling along the top 40% with (steel) cables facing towards the front. This causes the 60 foot poles to bend; stress. Under stress, they take on the 'curve' of a portion of a parabolic spar or support.

After the 8 tubular masts are pre-stressed into the form of a parabola-curved section, a small diameter steel wire is used to lay a screen reflector surface over the curved surface, at intervals of approximately 5 cm.

The reflector should be sited within 0.5 degree beam heading to the desired transmitter (source) to maximize gain. The procedure for this is described and is not complicated to duplicate. As each of the eight tubular supports are set into place and individually stressed into the parabolic curve, you need a surveying transit and the skills to use it.

Once the reflector is up, and the screen wires in place, the fun begins. This antenna is basically the top-third of a full parabolic. Think of the 60 foot height and 120 feet width as the top-centre 1/3 of a much larger antenna measuring close to 160 feet in diameter. And the bottom 1/2+ is 'buried' in the ground; and invisible(!).

All of this is nothing but a passive reflector; it collects (captures) signal from a distant source and focuses all of the collected energy to a small, well defined, point; a focusing device. The 'point' where the signals caught by the reflector focus is:

1) Just slightly above ground level (that's convenient when you work on the feed antenna, which is the only 'tweeking' done,);

2) In a spot or region approximately one wavelength wide, a half wavelength tall and not over 1 wavelength deep (front to back).

Into this focus area you place a very small antenna; typically a dipole plus reflector plus single director; sometimes without the director.

The smallish feed antenna can be channelized (i.e., for a single channel), or broadbanded (a log or multiple-channel yagi).

As a practical matter, you take the feed antenna and starting from a calculated point 'wander about' with the feed antenna making small adjustments to its location; reading the received signal out on an FSM. Remember this is just above the ground level so there is no tower climbing or dangerous work associated with finding the strongest signal.

Multiple feeds (for channels spread from band I to band III to UHF originating at the same transmitter site) are a bit of a problem (solvable) because they all would like to be at the same focus point!

The Half-Bolic is capable of working over an area of up to 40 degrees beamwidth; meaning if one station is 360 degrees (due north) of you, the Half-Bolic will capture and focus signals across a window from 340 to 020 degrees. And each different beam heading will have its own focus point.

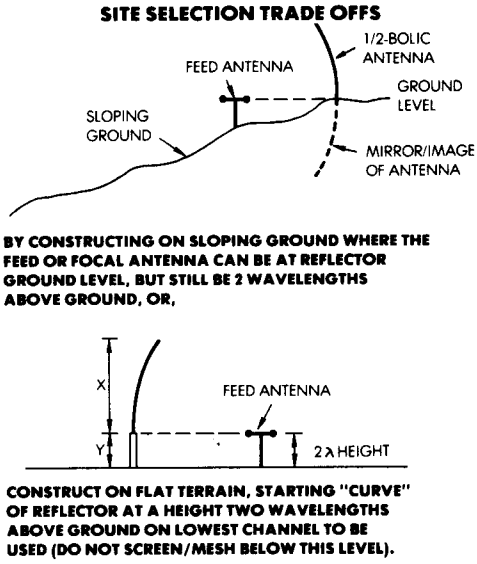
Because the forward gain (in the 60 x 120 foot size [18.32m X 36.62m]) is so high, band I and III signals over distances of 250 km are commonly covered with TASO Grade 2 (and 1) signals in North America. At bands IV/V the gain can be even greater but the builder must use extreme care to maintain the reflector surface accuracy +/- 2 cm for proper single point focusing at UHF.

1) Probable cost: For openers there is nearly 150 metres of sizeable support steel pipe. And kilometres of wire. With typical Kiwi ingenuity, perhaps $5,000 plus lots of donated labour.

2) Probable construction time: The first time you build one will be a serious learning curve; stringing the reflector wire is slow and tedious. Several hundred man-hours minimum.

3) Probable tweeking time. This one's easy; a few hours at most, assuming you built the reflector accurately. The feed-location focus point will be almost precisely where your plans said it should be and in actual fact in 15 minutes from construction finish you are likely to have the best pictures you will achieve.

TYPICAL SITE/HALF-BOLIC


SITE SELECTION TRADE OFFS
1/2-BOLIC ANTENNA
FEED ANTENNA
GROUND LEVEL
SLOPING GROUND
MIRROR/IMAGE OF ANTENNA
BY CONSTRUCTING ON SLOPING GROUND WHERE THE FEED OR FOCAL ANTENNA CAN BE AT REFLECTOR GROUND LEVEL, BUT STILL BE 2 WAVELENGTHS ABOVE GROUND, OR,
X
Y
FEED ANTENNA
2λ HEIGHT
CONSTRUCT ON FLAT TERRAIN, STARTING "CURVE" OF REFLECTOR AT A HEIGHT TWO WAVELENGTHS ABOVE GROUND ON LOWEST CHANNEL TO BE USED (DO NOT SCREEN/MESH BELOW THIS LEVEL).

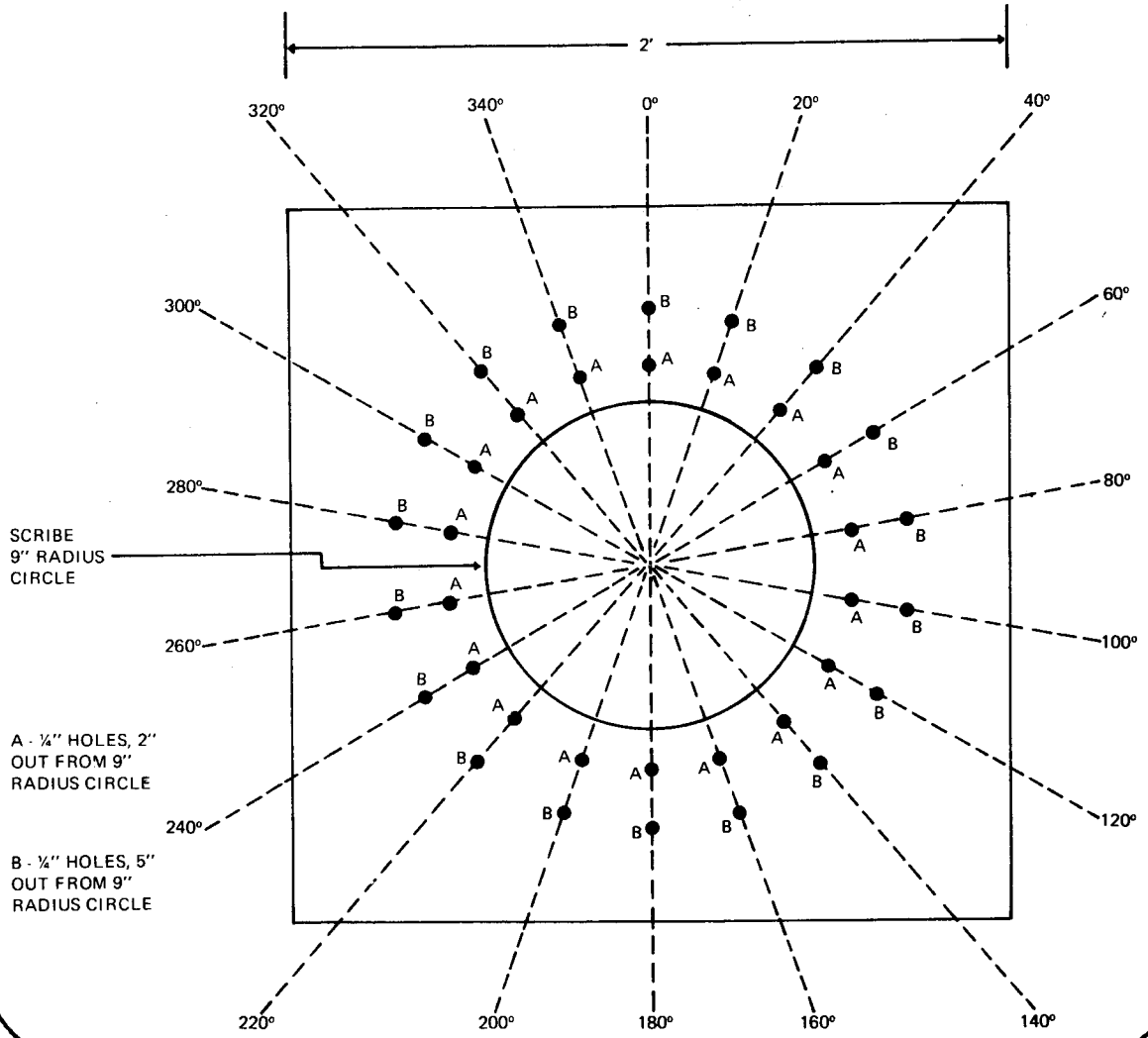
THE PARABOLIC DISH

This antenna is what you imagined a 'parabolic dish' looked like all along. It follows the same design criteria as the satellite dishes you have seen, with changes in the mechanical design/construction to allow low cost materials to be used. This scaling 'down' of materials is possible because antenna structural tolerance versus antenna performance is a function of wavelength. At satellite wavelengths, +/- 2mm is a big time error. At 600 MHz, +/- 1.5cm is an acceptable error. (NO, you cannot use wooden struts and chicken wire to build a low-cost satellite dish!)

A parabola is a unique mathematical shape; viewed from the front it looks like a large circle with the centre pushed in; not unlike an oversized cereal bowl (hence **dish**). The design requires any single point on the surface (again called the reflector) to be the same physical distance from a point in front of the dish (called the feed point) as any other point on the surface.

When the dish is 'pointed at' a distant TV signal source, the sizable reflector captures wavefront energy and redirects it (by reflection) back to the feed point. Because the capture area of the dish is large when

FABRICATING BACK / CENTRE PLATE FOR PARABOLIC DISH



compared to the dimension of a wavelength at the operating frequency, it collects wave front energy from many separate wave fronts simultaneously. This focused energy from multiple wave fronts is where the gain comes from. Where a yagi might only capture energy from a single passing wave front, the reflector captures far more from many wave fronts.
A dish of any size has a minimum operating frequency; determined by the number of wavelengths which will fit side-by-side into the dish at any instant. The width (or height) of the dish is called its **aperture** and if the structure is to function like a parabolic antenna, this aperture must be approximately 3 wavelengths across as a minimum.

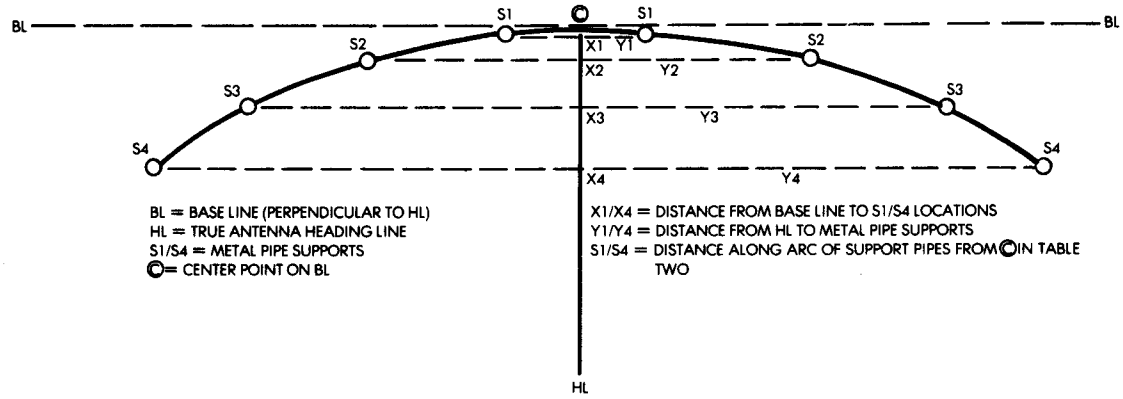
This establishes that a parabolic antenna of 12 metres aperture (40 feet) functions down to a frequency of approximately 80 MHz. A parabolic antenna of approximately 18 metres (60 feet) functions down to a frequency of approximately 50 MHz.

But real gain comes only when the reflector surface is **much** larger than its minimum operating frequency dimension. As an example, consider the probable gain of a parabolic antenna 12 metres in aperture.

EXPECTED GAIN / PARABOLA 12 METRES

Frequency	Aperture/Waves	Gain
80 MHz	3.2	10 dB
175 MHz	7	17 dB
230 MHz	9.2	18 dB
470 MHz	18.75	23 dB
600 MHz	24	24 dB
800 MHz	32	25 dB

OVERALL STRUCTURE PLAN/ HALF BOLIC ALIGNMENT TO SIGNAL PATH



At the very lower limits (80 MHz in our example) the antenna's feed focus point is poorly defined (i.e., does not seem to be in a precise location) while at 470 MHz where the gain begins to become substantial (23 dB) the focus point will be razor sharp; a well defined 'point' .

The Parabolic Dish construction described in our report makes use of commonly available materials (redwood or cedar for the dish spars, poultry/chicken/rabbit mesh for the reflector surfacing). This is acceptable at VHF (and the lower UHF range) because a dish's gain and reception beamwidth allows some user error. Not much, but some.

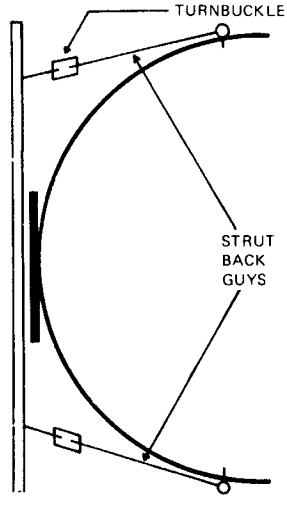
The amount of error is described as a function of wavelength at the operating frequency. The general rule of thumb is that if your completed parabolic surface approximates a true parabola to within +/- **1/32nd wavelength**, the antenna will perform to within a couple of dB of its paper-rated (i.e., computed) gain. The +/- 1/32nd wavelength 'error factor' is reasonably practical using the construction techniques and materials chosen. That works out to +/- .117 metres at 80 MHz, +/- 4 cm at 230 MHz, +/- 2 cm at 470 MHz and +/- 1 cm at 800 MHz.

Eighteen (18) struts are created from redwood (preferred material), or cedar to build a 20' (6.1 metre) dish. The struts are anchored at one end to a plywood (or aluminum) centre 'plate'. Television mast guying wire (7-strand, galvanized or facsimile) is used to form a 'stress ring' from strut to strut to strut; a complete circle. As tension is applied to the guy wire the struts bend (inward) and begin to take on the shape of a parabola of evolution. In effect, you use **straight** wooden struts, bent inward under tension, to form a parabola.

When this is completed, the surface of the dish is applied using 1/2" to 1" (maximum opening width) poultry cloth (screening). The wooden struts are for support; the screen is the reflector surface.

The entire screen reflector is either built-in-place or a boom truck used to lift it after construction (typically built 'on its back' with the struts bent inward/upward) to the support tower/pole(s). If the reflector is lifted

PARABOLA OF EVOLUTION



to a final operating position which is barely above ground (something you can do if on a hilltop where additional height is not important), the feed can be on a tripod mount at ground level (not dissimilar to the Half-Bolic feed mounting at ground level). If the dish is elevated (some have been 30+ metres above ground) the feed must be supported in front of the dish, at the focus point; this requires a little extra work to support the feed rigidly in place.

Construction of a 5 to 12 metre aperture dish is not complicated (the plans are very complete) but the structure you end up with must be made 'wind friendly'. One way to do this is to substitute (at increased expense) aluminum channel for the wooden spars, aluminum plate for the plywood centre plate. If the dish is to be functional at heights well above ground, the aluminum design approach is recommended (and also covered in the plans). If the lower lip of the reflector surface will be just above ground, with the reflector mounted on a short steel tower or wooden/concrete (utility) pole, you can back and front guy the structure using non-metallic guying materials.

1) Probable Cost: From $300 to $600 in materials for 6 to 12 metre versions in redwood or cedar; less the feed antenna. An all aluminum version would be 2 to 4 times as much.

2) Construction Time: From 30 to 50 man hours for versions from 6 to 12 metres in size, plus extra time to mount if not attached at ground level to tower or pole.

3) Tweeking Time: At ground level mounting, 1 to 2 hours after mounting.

ACCESS TO CONSTRUCTION DETAILS

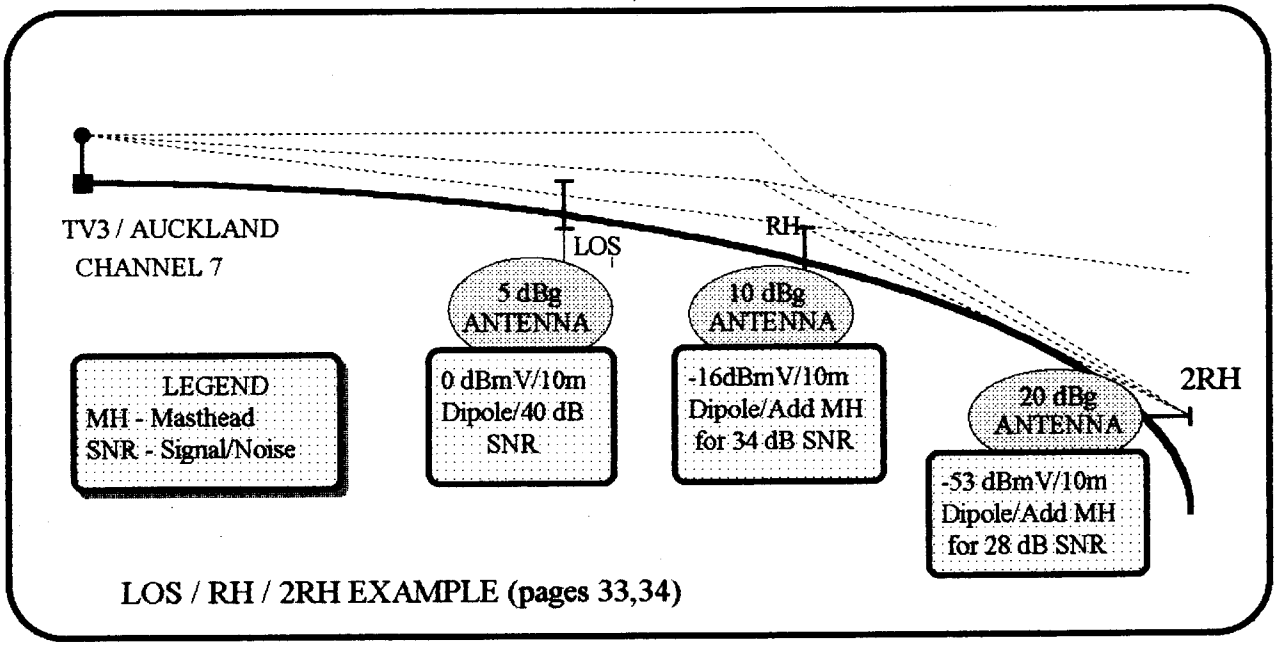
All three of these antennas have been designed, built and refined through a decade or more of routine use in the cable TV industries of North America and Europe. The author has built each several times; the 6-12 metre parabolics several dozen times for different cable firms.

Each of the three formats has been extensively described in print and copies of these printed 'how-to-build-it' articles are available for reasonable copying fees. See page 38 (order form) in this issue of Tech Bulletin.

PROPAGATION PATHS

Assume this model:

1) A television transmitting antenna is placed on a tall mountain (1500m) such that the visual line of sight range is 150 km. The signal level from the transmitter is measured on a test antenna of known gain 10m above ground; at the visual horizon of 150 km.



LOS / RH / 2RH EXAMPLE (pages 33,34)

LOSSES TO BE ANTICIPATED FROM LINE OF SIGHT OUTWARDS

RECEPTION ZONE	APPROX. DISTANCE	DIPOLE SIGNAL/10M	ASSUMING NORMALIZED COVERAGE AREAS CH. 1	CH. 11	CH. 27	CH. 43
Line Of Sight/**LOS**	50 km		0 dBmV	0 dBmV	+1 dBmV	+4 dBmV
Radio Horizon/**RH**	66 km		-13 dBmV	-16 dBmV	-19 dBmV	-20 dBmV
1.5 RH	100 km		-47.5	-50.5	-53.5	-54.5
2 RH	133 km		-50	-53	-56	-57
2.5 RH	167 km		-52.5	-55.5	-58.5	-59.5
3 RH	200 km		-55	-58	-61	-62
3.5 RH	233 km		-57.5	-60.5	-63.5	-64.5
4 RH	266 km		-60	-63	-66	-67

NOTES: Losses after LOS and Radio Horizon combination of worst case fading and signal spread; all levels in dBmV (0 dBmV = 1,000 microvolts) from resonant test dipole 10 metres above ground.

2) Now the television antenna height is reduced (the transmitting power level remains constant) to a height (270m) that reduces the visual line of sight range to approximately 50 km. The same receiving antenna is once again used to measure the signal level from the new transmitting antenna height still at a distance of 150 km.

a) The signal level with the lower transmitting antenna height will be 57 dB lower than in the first (line of sight) instance.

b) If the signal level measuring exercise continues over sufficient time as to average out any short-term abnormalities, we would find:

1) From the median (long term average) signal level measured:

a) The signal will be 8 dB below this level 10% of the time;

b) The signal will be 16 dB below this level 1% of the time.

2) And, conversely:

a) The signal will be 8 dB above this median level 10% of the time, and,

b) 16 dB above this median 1% of the time.

3) The median signal level will fade very rapidly (i.e., scatter effect fading) from 6 to 16 dB except when there is a 'quiet atmosphere' and signal enhancement is taking place along the path.

4) The signal level will vary from 8 to 16 dB with a much slower fading (i.e., spread over several minutes time from peak to peak, null to null) except when there is enhanced propagation.

The design criteria for reception in the RH/2RH/3RH and 4RH 'zones' is to overcome the path loss associated with being 'below' the free space loss level, and, to compensate for the rapid fading associated with scatter propagation.

If you know or can deduce the actual signal level at a point known as the visual line of sight, you can in turn translate this number to the projected level at any RH/2RH/3RH/4RH point further 'out'.

5) The signal level decline per kilometre will typically be 0.075 dB per kilometre (.75 dB per 10km; 7.5 dB per 100km) for any point starting at the radio horizon and working outwards. This is shown in a table above.

An example might be as follows:

1) Projected signal contour for Auckland TV3 operating on channel 7 to a signal contour of 55 dBuV per metre: or in our language, **0 dBmV** (1,000 microvolts; 1 millivolt) on a test dipole at a height of 10 metres (see diagram, page 32).

a) Assume this to be at a distance of 50 kilometres; the visual horizon.

b) At the radio horizon (50 km + .33 of 50 = 66.5 km) the signal level is degraded by approximately 16 dB; and it becomes **-16 dBmV** on our test dipole. This 16 dB loss between visual horizon and radio horizon is what might be expected in the transition from

2RH NUMBERS/WORST CASE
133km/CH7/Visual Horizon Signal Level 0 dBmV

AT	SIGNAL LEVEL*
Visual Horizon (LOS)	0 dBmV/60 dBuV
Radio Horizon (RLOS)	-16 dBmV/44 dBuV
1.5 RH	-40 dBmV/20 dBuV
2 RH	-53 dBmV/ 7 dBuV

*/ using 0 dBg dipole antenna

	WITH 10 dBg ANT
Visual Horizon (LOS)	10 dBmV/70 dBuV
Radio Horizon (RLOS)	-6 dBmV/54 dBuV
1.5 RH	-30 dBmV/30 dBuV
2 RH	-43 dBmV/17 dBuV

2RH NUMBERS/AVERAGE CASE
133km/CH7/Visual Horizon Signal Level 0 dBmV

AT	SIGNAL LEVEL*
Visual Horizon (LOS)	0 dBmV/60 dBuV
Radio Horizon (RLOS)	-8 dBmV/52 dBuV
1.5 RH	-20 dBmV/40 dBuV
2 RH	-27 dBmV/33 dBuV

* / using 0 dBg dipole antenna

	WITH 10 dBg ANT
Visual Horizon (LOS)	10 dBmV/70 dBuV
Radio Horizon (RLOS)	2 dBmV/62 dBuV
1.5 RH	-10 dBmV/50 dBuV
2 RH	-17 dBmV/43 dBuV

LOS to RLOS and it is within this transition zone that fringe/near fringe reception techniques apply.

2) At a distance of 2RH (133 km) the signal level will be -16 dBmV minus 66.5 (km) x 0.075 dB or 4.99 (5) dB down from the visual line of sight point; **-21 dBmV** total.

a) To this we must add the worst case slow fade degradation (-16 dB); now we are -21 (+) -16 = **-37 dBmV** worst case.

b) And, we must add the erratic fading associated with scatter; worst case -16 dB. Now we have -37 dBmV (+) -16 dB = **-53 dBmV** total loss.

See diagram page 32 and table above.. At a distance of 133 km from TV3 / channel 7 Auckland, we would anticipate a signal level which in worst case is **-53 dBmV**. But, that's using a basic dipole for signal measurement, at a height of 10 metres. A 10 dB yagi at the same height would create -43 dBmV.

In this example, everything is against us; a full 16 dB has been subtracted for both rapid fading and slow fading (each). In the best case the signal levels could (1% of the time) be 32 dB stronger than this; or even greater during those rare interludes of favourable weather enhancement.

PROPAGATION ENHANCEMENT

If you function in an area outside of LOS propagation to nearby transmitters, you are well aware that TV reception levels vary through the day, day to day, season to season.

If some or all of your television reception arrives across paths that are basically 'over water', you have observed that improved signal levels occur:

1) From sun up to midmorning

2) From sundown through midevening hours

3) With added enhancement whenever a weather front runs parallel to the path with stable (higher pressure) air along your path and disturbed (stormy) conditions behind the approaching front.

Any increase in the moisture content (humidity) in the lower atmosphere enhances signal propagation. A marked temperature break (25C at surface; 10C at 2km elevation) creates a boundary line, or 'duct' as it is called, which transports distant VHF (and UHF) signals with much enhanced signal levels for as long as the duct persists.

The offshore breezes bring in cool air along coastal areas during the daytime, and reverse at night; a pattern for establishing ducts and for enhancing the over-water humidity content of the air.

When signal levels are good, you look like a hero to your client. When they are bad, well, you might take your telephone off the cradle.

Generally speaking, warmer daytime temperatures in the summer months create improved lower atmosphere conditions. A chart (see page 8 here) shows how average scatter level signals are as much as 8 dB stronger for any given time of day in the

November to May period than in the colder six months.

When you begin installing antennas with 20+ dB of gain, and equipping them with exotic low noise masthead amplifiers, anticipate that when reception conditions improve you may have some very strong signal levels to contend with. That's not all good.

Recall that any amplifier (even a masthead) has a maximum output capability; the sum of its internal gain plus the input signal applied. If the gain remains fixed and the input signal rises from a normal -10 dBmV to an overpowering +20 dBmV because of favourable weather conditions, you should anticipate a service call to 'fix those drifting pictures in the background'.

Amplifier overload has no easy cure; other than going to the antenna site and tossing a few fixed pads in the line between the masthead and the antenna thereby reducing the input to the masthead to a level the amplifier can cope with.

The solutions:

1) AGC. Not the cheapest solution, but the least troublesome. The channels are individually run through automatic gain control amplifiers and then combined to the common downline. If your primary path problem is large up-fades, the AGC range can be field set so you operate in normal mode just above the point where the AGC takes hold. As the signal comes up, the AGC holds the output to your predetermined level.

2) Switching in pads. Route the antenna-to-masthead line so it runs through a set of (75 ohm/'F' fitting) coaxial relays. In the off mode, the signal goes directly from antenna to masthead(s). In the on mode, the signals are diverted through some number of fixed attenuators (such as 20 dB). The main problem with this is that somebody has to be able to control the coaxial relays from a remote location, or go to the antenna site to switch the pads 'in'.

3) Switching to smaller antenna. If a 20 dB up fade is capable of driving your amplifier string into overload, have a smaller (lower gain) standby antenna at the site. A remotely controlled coaxial relay will allow you to reduce the off-air input by the difference in gain between the 'big array' and the small array.

4) Consider a masthead with a greater output capability; assuming you are not operating a cascaded line-amplifier string on the transmission line following the masthead. Most mastheads function to outputs of +40 / 46 dBmV (100 to 106 dBuV). There are a few on the market with output capabilities in the 50 dBmV (110 dBuV) region. Unfortunately when the output capability increases, so also does the masthead's noise figure. Your trade off is better signal handling capabilities for lower ultimate system threshold sensitivity.

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TECH BULLETIN TOPICS

TB9301: Co-channel elimination, antenna phasing techniques [Released 01-06-93].
TB9302: Weak signal techniques, antenna + masthead practices [Released 01-06-93].
TB9303: UHF weak signal techniques, parabolic dish construction (you are reading this issue); [Release date 15-07-93].
TB9304: Identifying, curing television interference sources [Release date 15-09-93].
TB9305: Master/community aerial techniques on a budget [Release date 15-11-93].

Available by subscription or by single copy; see ordering forms last two pages here or contact R.B. Cooper, P.O. Box 330, Mangonui, Far North (FAX 09-406-1083).

ASK COOP

Robert B. Cooper began a professional career in weak signal TV reception in 1956 as U.S. magazine **RADIO ELECTRONICS** engaged him to prepare a regular feature column on this subject. Creator of 15 books, more than 2,200 magazine articles, 'Coop' is now a resident of New Zealand's Far North where he continues to research and write.

• "The description of TV3 reception in Kaitaia (TB9302) fascinated me. Where can I learn more about this type of propagation? Is it true the signals do not fade?"
K.M., New Plymouth

Knife-edge signals do not fade more than +/- 3 dB provided both the transmitting tower and the receiving point have LOS (line of sight) to the knife-edge point. In the early days, this form of VHF-UHF-SHF propagation was also known as 'obstacle gain'; i.e., with a sharply defined physical object on the path between the two points, there was obviously signal-gain between the two points since the received signals often reach levels 25 dB stronger than line of sight for the same distance.

Start with Department of Survey & Land Information 1:250 000 series maps. Pin as many as it takes on the wall, aligned with one another, so you can follow the path from the transmitter to the desired receiving region. Use a straight edge and draw the path on the map (Survey & Land will laminate the maps so you can draw-on and rub-off markings).

LOS is determined by the formula :

D (km) = 4.124 times the square root of the transmitting antenna height in metres

Here's a quick table that will provide guidance.

Metres High	LOS Range
300	71.31km
400	82.37km
500	92.23km
600	100.87km
700	108.95km

We have one object (the mountain peak on the path) and *two* ends to the circuit. The transmitting antenna must be able to 'see' the mountain peak above its visual horizon.

If the peak is 700 metres and the elevation of the transmitting antenna is 400 metres, we cannot stack the two (i.e., 1,100 metres) to determine the LOS between one point and the horizon. We must calculate each individually and then add together the two LOS ranges to determine total LOS.

So, the line of sight for 400 metres is 82.36km while the LOS for 700 metres is 67.71km; 150.07 km total path length if each was right at the horizon of the other.

You will probably need Survey & Land 1:50,000 series maps to get a good 'profile' of the peak. It needs to lay across the path (i.e., at right angles to the signal crossing it), be sharp-edged towards both the receiving point and the transmission point, and not have any almost-as-high peaks along the way between the two. Ideally, the transmitter looks out over water or flat land for much of its distance towards the obstacle gain peak; then the refracting peak rises quickly (suddenly) to its height.

Towards the receiving point, the obstacle peak must be able to 'see' the receiving point also.

The 'shape' and 'size' of the receiving zone will depend totally upon the shape of the obstacle gain peak and its own dimensions; and, the frequency of the signal. VHF signals tend to make larger 'reception zones' than UHF signals.

The reception zone is likely to be narrow (as narrow as a few wavelengths across) but can be several km long.

Questions for Coop? Address to: R.B. Cooper, P.O. Box 330, Mangonui, Far North.